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Sacramento, California

EFFICIENCY EVALUATION
TRACY FISH COLLECTING FACILITY
Central Valley Project
California

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PREFACE

The Tracy Fish Collecting Facility was completed in the fall of 1956 and operation began in the spring of 1957. The facility is a unique installation for preventing fish entering the Delta-Mendota Canal. It was developed through an exploratory program conducted jointly by the Bureau of Reclamation and the Fish and Wildlife Service of the Department of the Interior during the years 1952 to 1954. Throughout the development program consultations were held and findings reviewed with the California Departments of Fish and Game and Water Resources. Representatives of these agencies convened from time to time as an advisory council. Upon completion of the facility the Bureau of Reclamation and the Fish and Wildlife Service undertook a joint testing, evaluation, and appraisal program. The findings of that program are recorded in this report.

The authors appreciate the assistance given to them by the many persons who aided in the conduct of the work and who assisted in editing the early drafts. Particular acknowledgement is made Messrs. R. A. Fredin and R. H. Lander of the Biometrics Unit of the Bureau of Commercial Fisheries at Seattle, Washington, for their help in outlining test procedures, to Mr. K. W. May for preparing the original draft of the chapter on mortalities after he left the Bureau of Commercial Fisheries, and to Mr. Stanley G. Jewett, Jr., Chief, Fish Facility Section, Bureau of Commercial Fisheries, Portland, Oregon, for his painstaking editing of the report while it was being formulated.

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CHAPTER I

SUMMARY AND CONCLUSIONS

A testing program to measure the efficiency of the Tracy Fish Collecting Facility and its various components and to develop criteria for its operation was initiated in 1957 and completed early in 1959. This was done as a joint undertaking of the Fish and Wildlife Service and the Bureau of Reclamation under inter-bureau agreement.

This report describes the facility briefly and gives a chronological account of the development of the testing program and of the techniques considered and employed as well as giving the findings and conclusions reached.

In the first series of tests an attempt was made to measure directly the efficiency of the primary louver array. Four methods were considered. In theory the simplest of these would have been to screen the entire flow of water downstream from the louvers to trap all fish which had escaped through the system. However, because of the large volume of water, 5,000 c.f.s., the great abundance of peat moss fibers present throughout the water, and because of the very large area which would have to be netted, this was obviously impracticable.

Another method involved the release of marked fish upstream from the louver array and recovering them in the holding tanks. Young king salmon, marked by clipping their fins, were first used in these trials but it was found that many of them failed to move through the secondary system. This delay cast uncertainty on the findings. Various kinds of dyes were used to color young striped bass in the hope that in this way they could be identified. Unfortunately, the dyes had such a strong affinity for the mucous covering the fish that none persisted for more than 10 minutes.

In another technique large known numbers of small striped bass were introduced into the canal ahead of the louvers during the daytime when the number of fish in normal migration would not be significant. Recoveries made in fyke nets below the primary system and in the holding tanks were compared. The results were inconclusive either because of hold-up in the secondary system or, as seems likely, loss of the fish through the louvers as a result of an impaired physical condition brought about by handling.

The final trials in 1957 involved the screening of a portion of the canal flow upstream and downstream from the louver array and of all of the primary bypasses. This technique resulted in a collection of data which indicates that the efficiency of the louver array in deflecting fish approximates 97 percent. This indication is based on several assumptions noted on page 27. Because this indication is, in part, hypothetical it was not accepted as conclusive.

Information was obtained during 1957 also on several additional factors that may have an effect on the efficiency of the louver system. Sample fishing showed that as velocity increases the proportion of striped bass moving into the first three bypasses also increases. It was evident that there was no size selectivity either by the bypasses or by the nets fishing in the primary canal. The greatest number of fish enter the canal and the bypasses during the night shortly after high low tide. Fish are deflected somewhat better at night than in the daytime.

In 1958 studies were limited to the secondary louver system and the results applied to the primary system. With velocities below 3 feet per second 76 to 86 percent of all fish under an inch in length were diverted into the bypasses. Losses of these very small fish increased with increased velocity. In nearly all tests with fish measuring 1.5 to 4 inches in length efficiency lay between 95 and 99 percent.

In a series of tests in which the bypass to approach velocity ratio was studied, best results for striped bass and king salmon were obtained with a ratio of 1.4 to 1 rather than 1.0 or 1.2 to 1.

A double line of louvers generally increases deflection efficiency.

Appurtenant facilities were studied in some detail and the findings are described. The Bureau of Reclamation found that the trashrack and rake were not efficient and that debris passing through interfered with bypass operation. A trash deflecting boom installed in early 1960 has greatly improved trash collection and, in turn, operation of the bypasses and holding tanks. The fish holding tanks were studied for adequacy of design and found to be satisfactory. The original fish-lift bucket was modified to improve its operation. Satisfactory equipment for making sample counts of fish was developed after several experimental designs had been tried. Studies were undertaken to determine the adequacy of the aeration, refrigeration, and water circulation systems of the tank trucks. Tables were formulated for use in determining the number of fish of various sizes that make up an optimum tank truck load for distribution to release sites, and a method for making sample counts was developed.

Mortality in the entire collection system was investigated carefully. In one test it was less than 6 percent for 1-inch long striped bass held in a live-tank for 24 hours. In another test striped bass of the same size held for four days had under 4 percent mortality. Observations made when fish are unloaded indicate that these mortalities are not generally exceeded in day-to-day operation.

From the data secured and observations made it may be concluded that the efficiency of the Tracy Fish Collecting Facility ranges from 65% to nearly 100% depending upon the species of fish, their size, the velocity of flow, the ratio of the velocity in the bypasses to that in the channels and upon accumulations of debris in the bypasses. Efficiency is nearer the upper limit most of the time under normal operating conditions. Suggestions for maintaining maximum efficiency are listed in the findings of this study.

CHAPTER II

HISTORY AND NATURE OF THE TRACY FISH PROBLEM

Introduction

On September 27, 1956, the Tracy Fish Screen Advisory Council 1/ met and suggested a two year testing and evaluation program to determine the efficiency of the Tracy louver principle as applied in the Tracy Fish Collecting Facility. Since the Facility is a unique installation using a previously untried principle, such an evaluation was considered essential. Subsequently, arrangements were made with the Fish and Wildlife Service to assign personnel to participate in the program to be initiated February 1, 1957. An inter-Bureau agreement was approved on March 28, 1957 to cover the study (Appendix A).

On April 10, 1957 the Tracy Fish Screen Advisory Council met again at Tracy to formulate a study outline from a draft developed by Service personnel. As the work progressed only minor changes were found necessary in this outline.

In addition, two forms (Appendix B), which were designed for use in the study were reviewed and their use agreed upon. Form TO-80 was designed to provide a record of the objective of a test and the equipment, and method used; it also provided instructions to operating personnel so testing could be coordinated with day-to-day operation of the Tracy Pumping Plant and the fish collecting facility. Form TO-81 provided a record of test results and evaluations. This report has been compiled largely from the findings so recorded.

1/ Composed of representatives from the California Departments of Fish and Game and Water Resources, the Fish and Wildlife Service and the Bureau of Reclamation.

The Fish Screening Problem

The Sacramento-San Joaquin Delta is a sea-level maze of channels between low islands into which discharge the Sacramento, the San Joaquin and two lesser rivers draining California's Central Valley. Anadromous fishes spawn in the delta itself and in these rivers. With the construction of the Tracy Pumping Plant of the "Central Valley Project" by the Bureau of Reclamation these fish, particularly king salmon, striped bass, and shad became subject to diversion into the Delta-Mendota Canal, a unit of the Central Valley Project. To gain knowledge of the times of occurrence, size and movement of these fish, especially juvenile fish in their seaward migration, investigations were made by the Fish and Wildlife Service. Funds were supplied by the Bureau of Reclamation. The Service found that "Evidence is conclusive that in order to protect and maintain populations of king salmon, striped bass, and shad, positive means for preventing their passage through pumps must be adopted." "Traveling water screens" were recommended for this purpose by the Service. 2/

Adoption of the Louver Principle

In considering the Service's recommendation the Bureau of Reclamation concluded that before risking the high cost of traveling water screens, an experimental system should be constructed to try other screening methods. Accordingly, a "Pilot Fish Screen Structure" was designed in consultation with the California Department of Fish and Game. This included traveling screens, stationary screens, and a California-designed sloping stationary screen.

2/ Studies of the Fishery Resources in the Sacramento-San Joaquin Delta in Relation to the Tracy Pumping Plant. United States Department of the Interior, Fish and Wildlife Service, Branch of Fishery Biology, Central Valley Investigation. January 31, 1950.

A joint study team of Reclamation engineers and Service biologists was established to evaluate these screens and to consider others which might be promising. This team began work in 1951 and continued until September 1, 1955. It developed and established the practicality of the louver principle of deflecting fish (Patent No. 2,826,897, March 18, 1958). The work of the team is described in a joint report of the Bureau of Reclamation and the Fish and Wildlife Service.[3/]

The present "Tracy Fish Collecting Facility", constructed in accordance with criteria outlined in the joint report and adopted by the Tracy Fish Screen Advisory Council, was placed in operation in February 1957.

Description of the Tracy Fish Collecting Facility

The Fish Collecting Facility (Figures 1 and 2) lies athwart the entrance to the intake canal of the Tracy Pumping Plant. The canal is 84 feet wide at that point and water depth varies from 21 to 26 feet depending on the tide. Volume of water flowing through the canal varies from a minimum of 775 c.f.s. (one pump operating) to a maximum of 5,100 c.f.s. (six pumps operating plus incoming tide). The louver structure, placed on 15-degree angle to the direction of flow, extends a distance of 320 feet across the canal. Four vertical bypasses, each 6 inches wide, are incorporated at 75-foot intervals along the face of the louver facility.

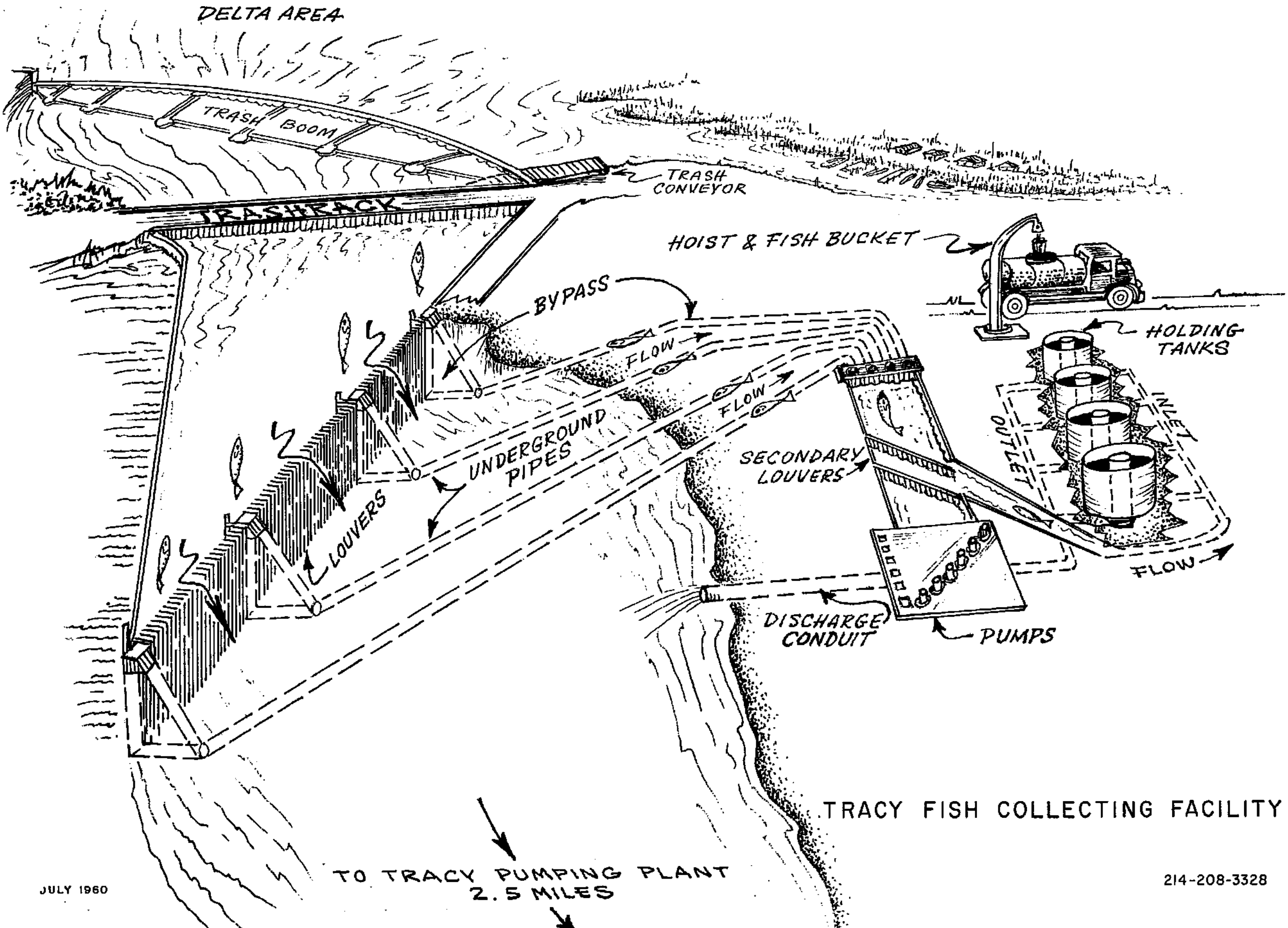
3/ Fish Protection at the Tracy Pumping Plant, Central Valley Project, California. United States Department of the Interior, Bureau of Reclamation, Region 2, Sacramento, California, and Fish and Wildlife Service Region 1, Portland, Oregon. February 1957.

As the fish move downstream with the flow they are carried down and into the bypasses which lead into 36-inch diameter concrete pipelines, each of which discharges through a gated orifice into a common 8-foot wide, 120-foot long secondary channel. The pipelines vary from approximately 185 feet to approximately 300 feet in length. The approach velocity at the bypass entrances is influenced by: (1) the number and size of the main bypass pumps operating, (2) the position of the slide gate controlling that particular bypass, and (3) the tides. Total bypass flow into the secondary channel within the limitations of these conditions, averages about 135 c.f.s.

To concentrate fish in a smaller volume of water, a second louver system consisting of a double line of louvers (Figure 3) placed on a 15-degree angle to the direction of flow deflects them from the secondary canal into a bypass terminating in holding tanks. To separate the fish from the peat-moss-laden water a flow of cleaned water is introduced just above the bypass. Final flow into one of the four holding tanks amounts to approximately 10 c.f.s. when the Tracy pumps are drawing their maximum of 5,100 c.f.s.

Fish concentration per unit volume of water is assumed to be proportional to the amount of water bypassed. Thus, the concentration of fish in the holding tanks is 640 times as great as in the forebay in front of the primary louvers and 40 times as great as in the secondary canal just ahead of the first set of secondary louvers.

Vast quantities of peat moss suspended in the flow would accumulate within the holding ponds and impair respiration of fish if it were not separated out. Separating the fish from the peat-moss-laden water is accomplished by use of a traveling screen on the left side of



TRACY FISH COLLECTING FACILITY

JULY 1960

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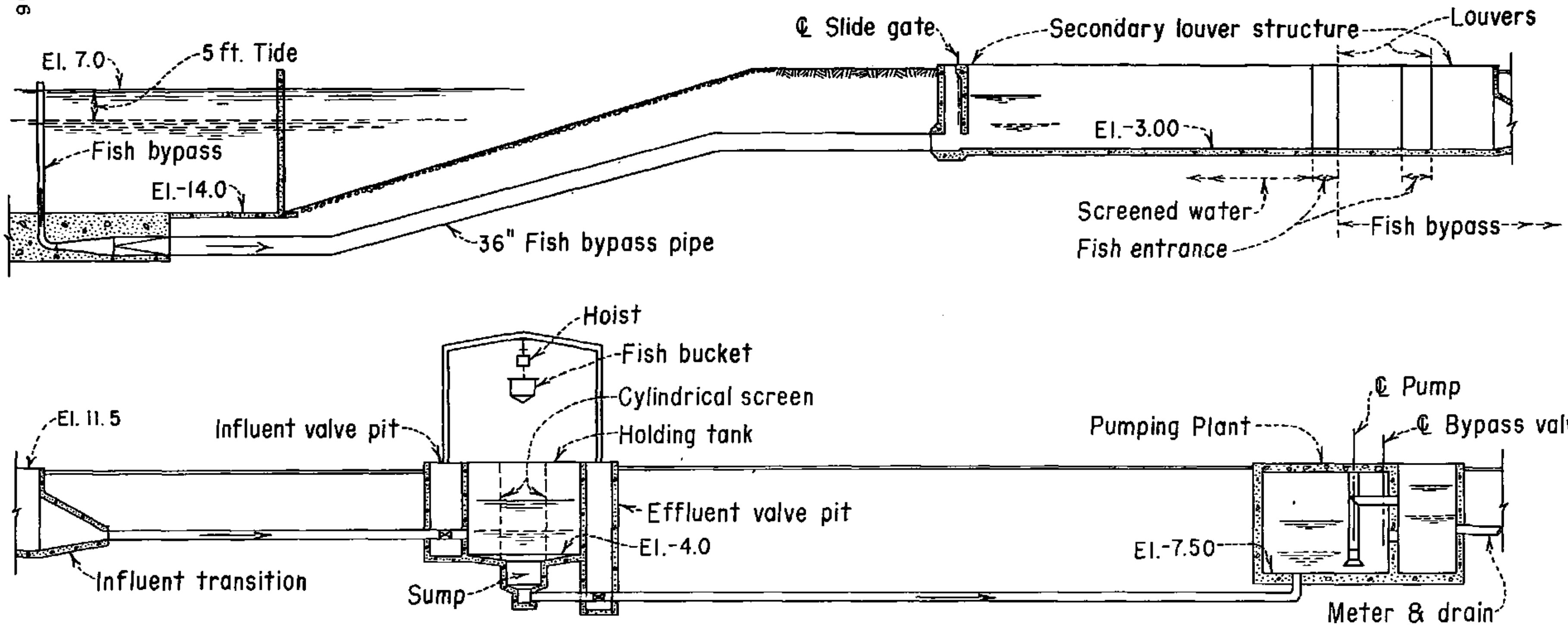
Fig. 1

AUGUST 13, 1956



SECTION THROUGH COLLECTION SYSTEM

Fig. 2

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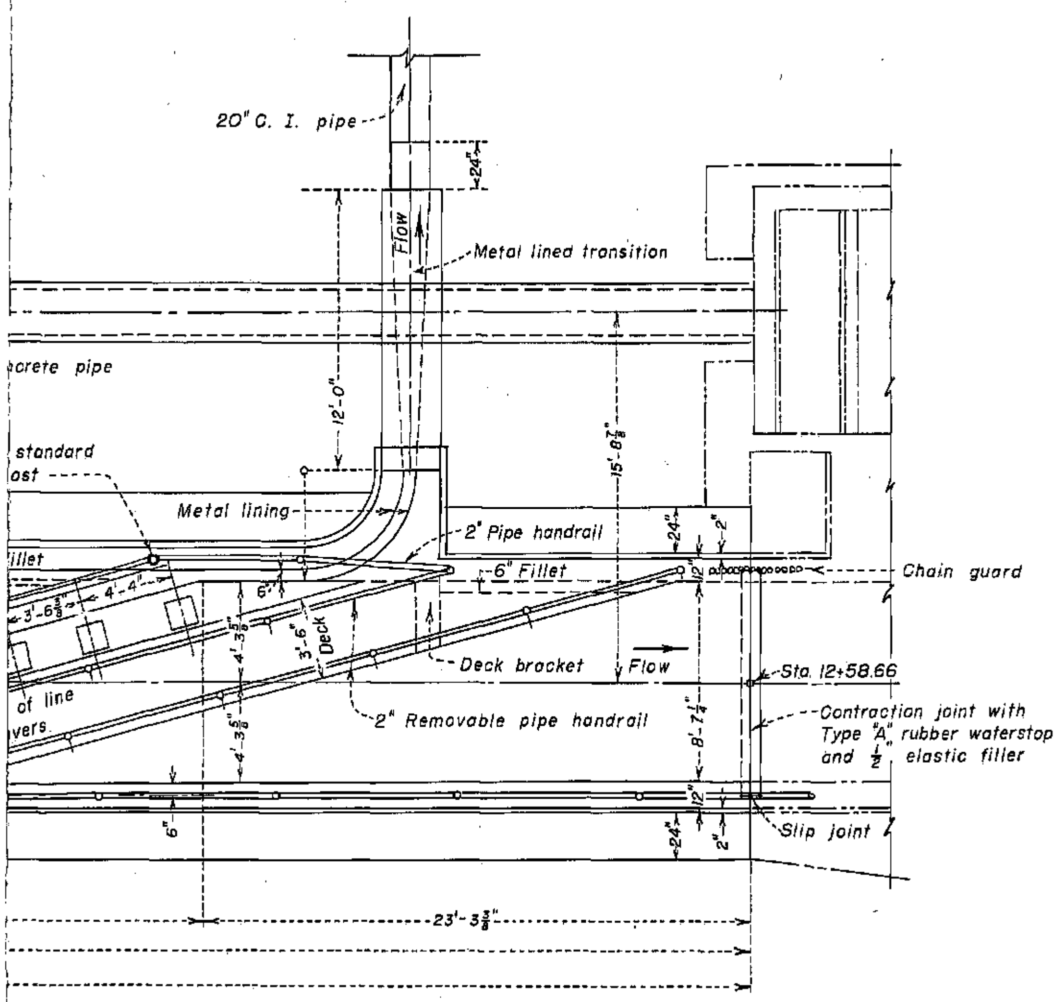


SECONDARY LOUVER STRUCTURE

the channel and downstream from the secondary louver structure. This screen picks up the fibrous debris from the water which is then pumped back and introduced along the left side of the secondary louver structure above the louvers. The debris-free water flows along the wall of the secondary louver channel into the bypass into which the fish are deflected. The uncleaned water, of course, passes through the louvers to be pumped back into the canal downstream from the primary louver system. To adjust and measure the flow there is a 24-inch butterfly valve and a 24-inch by 16-inch venturi meter in the screened water line.

Four holding tanks, each 20 feet in diameter and 15.5 feet deep are used to accumulate and hold the fish for loading. A system of valves permits collection in any selected holding tank. Appurtenant piping, valves, fish transporting bucket, monorail hoist, and aeration and other equipment are used to assure satisfactory collection, holding and efficient removal of the fish into a transporting truck. An eight-foot diameter, cylindrical, wire mesh screen centered in each holding tank retains the fish but permits water to pass through to be drained away from a sump at the bottom.

When the fish are being transferred from a holding tank to a hauling truck, flow is routed to another holding tank. The fish along with 500 gallons of water are retained in the holding tank by a nine-inch metal band around the bottom of the cylindrical screen. To remove the fish a 500-gallon capacity bucket is lowered within the cylindrical screen down into the holding tank sump, then the screen is raised a few inches, and the fish are flushed into the bucket. A hoist mounted on a rail raises the bucket up and it is moved into loading position over a special fish truck having water cooling equipment. As soon as the fish are loaded into the truck they are hauled to one of several downstream points toward San Francisco Bay far enough to escape the influence of the Tracy pumps.

The water surface in both the main and secondary louver structure and in the holding tanks fluctuates with the tide. To draw water through the secondary louvers and the collecting facilities there are two pumping plants, one for the holding tanks and another for the secondary louver channel.

The quantity of water passing through the fish collecting facilities depends on the number of Tracy pumps operating and on the tidal fluctuation. Each of the Tracy pumps will pump from 775 to 850 c.f.s. depending upon the tidal stage and the water level at the pumping plant discharge pool. With all six of the Tracy pumps in operation, the discharge will vary from 4,650 to 5,100 c.f.s. The maximum velocity approaching the fish collecting facilities of approximately 3.9 feet per second occurs a little after low tide. All of this water must pass the fish collecting facilities. The quantity of water passing through the main louver structure due to the tidal fluctuation alone varies up to about 800 c.f.s. in either direction, depending upon the stage, direction, and magnitude of the tide and the number of pumps in operation.

CHAPTER III

FACTORS AFFECTING LOUVER EFFICIENCY

In this chapter are discussed the principal factors that influence louver efficiency. During the course of the many tests undertaken, much was learned about the effect of these factors as applied to the prototype facility.

The findings concerning louver efficiency are restrictive to the species of fish and water conditions at Tracy, and the application of Tracy findings to other areas and fish without verification is not recommended.

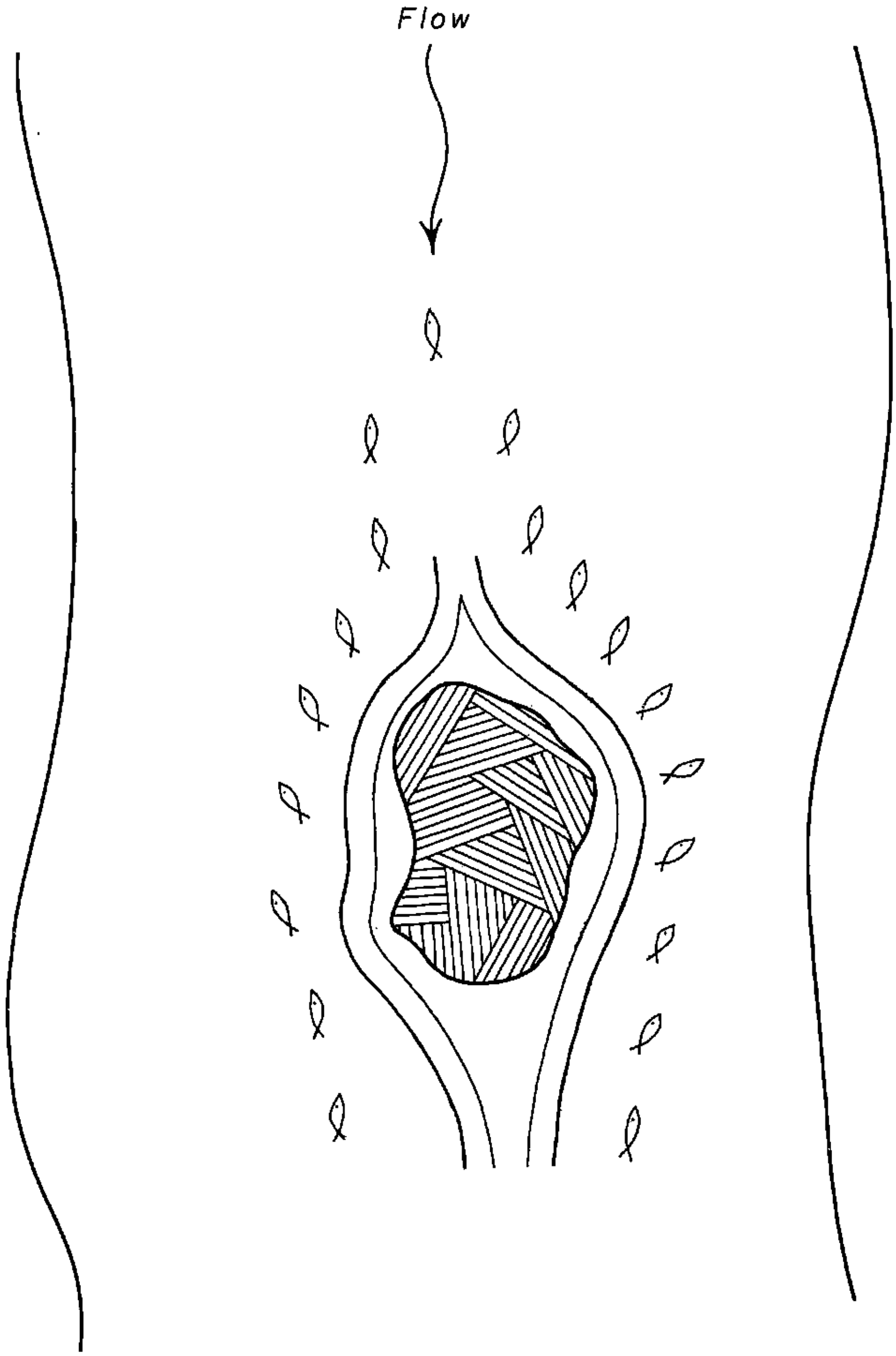
Support for this position comes from the knowledge that fish reactions vary with environmental conditions such as water temperatures and turbidity, as well as with species. Therefore, in considering factors which influence louver efficiency, a knowledge of fish behavior in each specific situation becomes important.

Fish Reaction to Louver Array

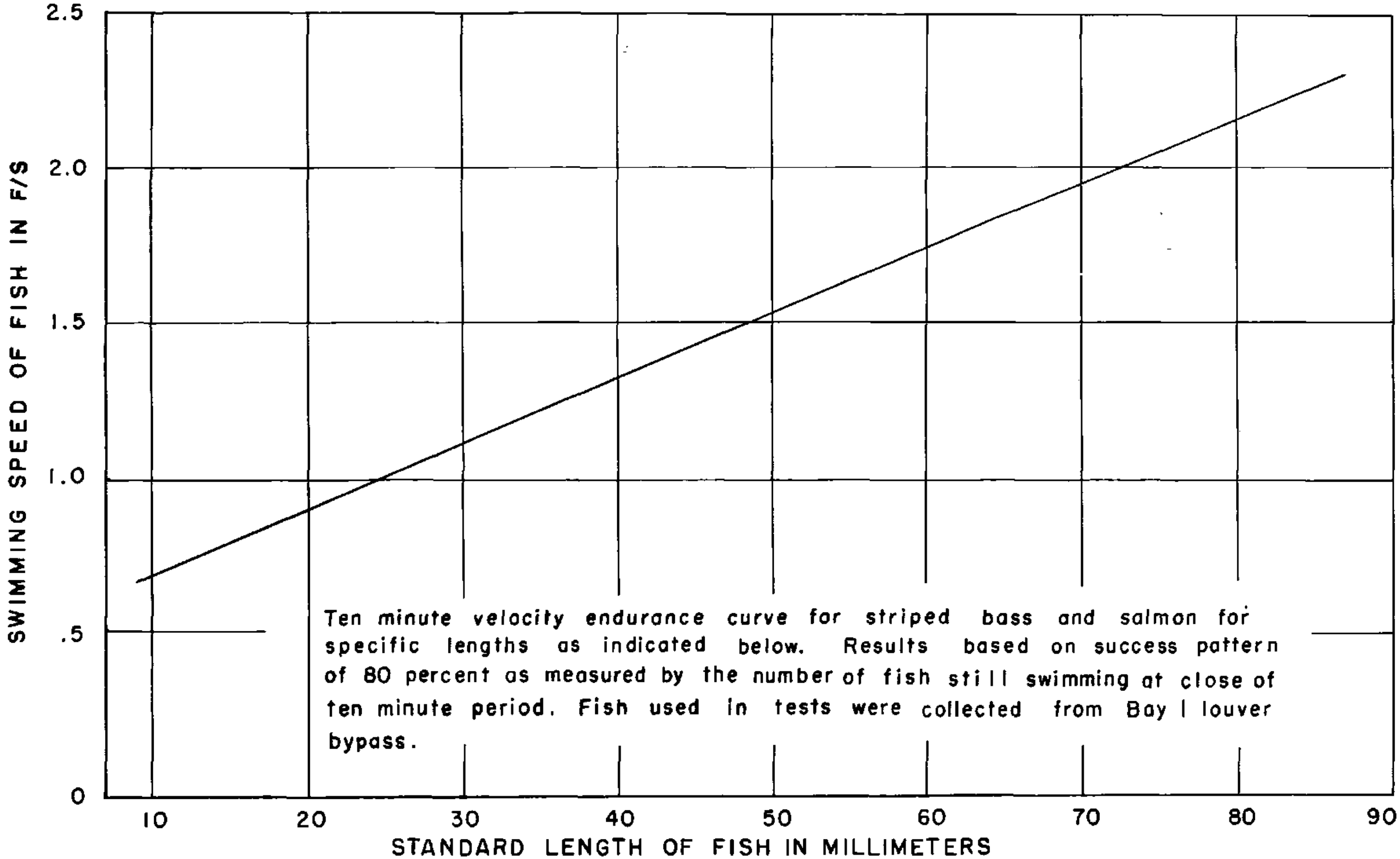
From thousands of daytime observationsit was noted that the normal position assumed by young king salmon, striped bass, catfish, shad, and even frog larvae while passing downstream is tailfirst. In swiftly flowing streams this position provides fish with the necessary control to avoid obstacles. Assuming a boulder to be the obstacle, the position of the fish under high velocity flows would be as illustrated in Figure 4. Exceptions to this occur if: 1) the rate of flow is so reduced, as in a dam forebay, that fish must swim headfirst to attain movement; 2) the fish are frightened to the extent that they swim wildly in any direction; 3) the fish are too weak to maintain a position heading directly into flow; or 4) the fish are apparently seeking suitable flow conditions for downstream passage.

Fish generally seem able to detect readily the presence of an obstruction in their downstream path even in swiftly flowing streams. Screen structures placed across a stream at 90 degrees will stop downstream migrants just upstream (a matter of several inches to several feet) provided their maximum swimming speed (Figure 5) is greater than the approach velocity. Sensing that their downstream movement has been blocked, they then begin to search for passage through. While searching they must overcome the current to avoid being impinged on the screens. If we assume that the approach velocity is 1.5 feet per second and that the fish are holding a position directly into the flow, they must maintain a swimming speed of 1.5 feet per second to avoid being carried onto the screens. Should they veer to the right or left at an angle of 30 degrees while searching, they must increase their swimming speed to 1.7 feet per second; if they veer off at 45 degrees, they must swim at the increased rate of 2.1 feet per second; and if they swing over to 60 degrees which would not be uncommon, they must increase their swimming speed to 3.0 feet per second to avoid being impinged on the screens. Velocity of flow is thus a critical factor in the ability of fish to maneuver while seeking safety.

Where obstacles are angled to flow, as are the Tracy louvers, fish are relieved of searching for downstream passage; their normal instinct to migrate in the direction of flow is satisfied as they pass downstream by merely deflecting away from the structure. Further, such structures can be so angled that they will deflect even very small fish



POSITIONS OF FISH AVOIDING AN OBSTACLE
IN TRAVELING DOWNSTREAM



SWIMMING SPEED AND ENDURANCE OF YOUNG STRIPED BASS AND SALMON
1955

Fig. 5

SEPT. 30, 1955

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(e.g. third of an inch long striped bass) in relatively high velocities (4 to 5 feet per second).

Fish can be deflected vertically as well as laterally by placing a sloping obstacle in their path. Whether or not fish can react as readily to a sloping obstacle as a vertical one was not determined in these studies, but it is presumed that lateral movement is easier than vertical movement and that fish therefore respond more readily in a lateral direction as velocity increases.

Horizontal Louvers

Horizontal louvers underwent several months of study and test during 1953 by the U. S. Fish and Wildlife Service biologists and Bureau of Reclamation engineers. Although it was found that fish were deflected efficiently, operating problems could not be overcome. To function, a certain depth of flow must be maintained over a horizontal louver structure. This overflow must serve as the fish bypass. At Tracy the water surface within the intake canal fluctuates with the tide and with changes in the number of pumps operating. Thus the depth of the flow over any fixed crest elevation varies up to seven feet. This wide variation complicates the possibility of recovering fish. Cleaning such a facility is another problem. Raising it up and out would mean lifting a heavy bulky structure and, because the louver slats are positioned horizontally and arranged on a slope in place of vertically, trash removal would be more difficult.[4/]

Swimming Speed in Relation to Velocity of Flow

The position of a fish moving downstream along a vertical louver system is determined by the size of the fish, the angle of

4/ Recently the Washington Department of Fisheries has tested several experimental horizontal louver structures and they now have a prototype in operation in Baker Lake, Washington.

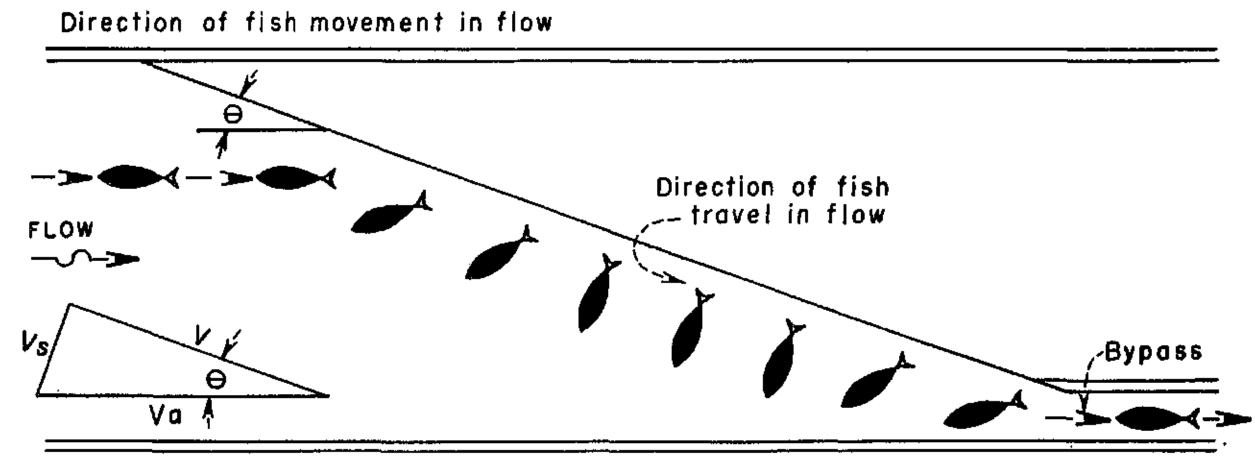
the line of louvers, and the velocity of the flow. At velocities not requiring maximum swimming effort, a fish usually moves downstream tailfirst and parallel to the flow with momentary lateral movement away from the louvers (Figure 6b). When velocities exceed swimming speed, it was observed in the early Tracy studies, particularly in slow-motion films, that fish orient themselves to the line of louvers at angles from it ranging up to 90 degrees (Figure 6a). The magnitude of the change in orientation is a function of the velocity of flow and the angle of the line of louvers. A vector diagram (Figure 7) shows the relationship of these factors.

In using the vector diagrams to analyze any given set of conditions, the approach velocity may be resolved into two components: $\underline{V}$ which is parallel to the line of louvers and $\underline{Va}$ which is at right angles to the individual louver slats. The speed at which a fish must swim to overcome the force of component $\underline{Va}$ and remain at a constant distance from the line of louvers while moving along component $\underline{V}$ is represented by $\underline{Vs}$. The swimming speed, $\underline{Vs}$, is related to the approach velocity as $\underline{Vs} = \underline{Va} \sin \theta$ where θ is the angle of the louver line. Table 1 shows the swimming speeds which a fish must maintain to pass along a line of louvers for selected combinations of approach velocity and louver system angle. For example, a 1-inch fish capable of swimming 1 foot per second can theoretically maintain position in an approach velocity of 7 feet per second at a louver line set at an angle of 8 degrees.

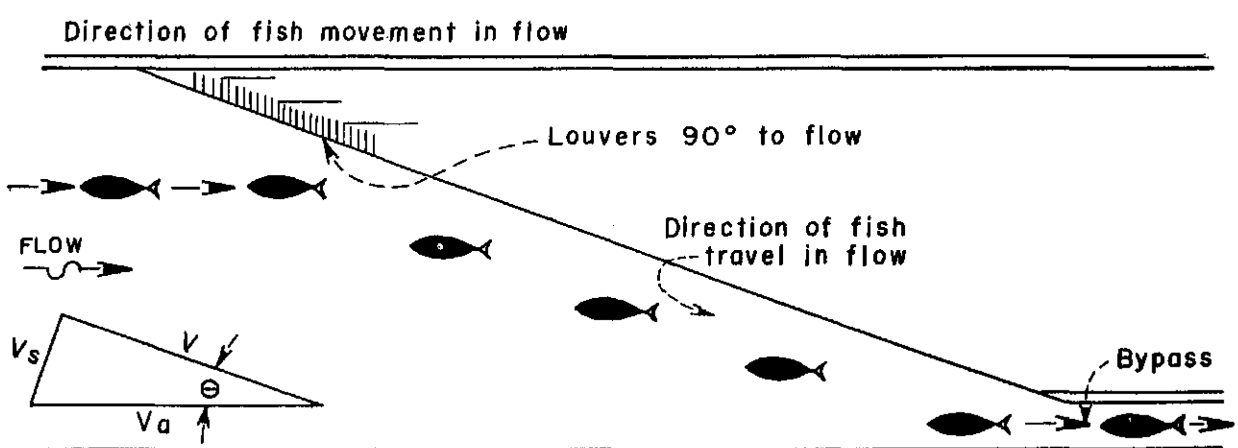
Angle and Spacing of Louvers

Louver efficiency can be drastically influenced by the angle of the line of louvers, the spacing of the individual louver slats, and

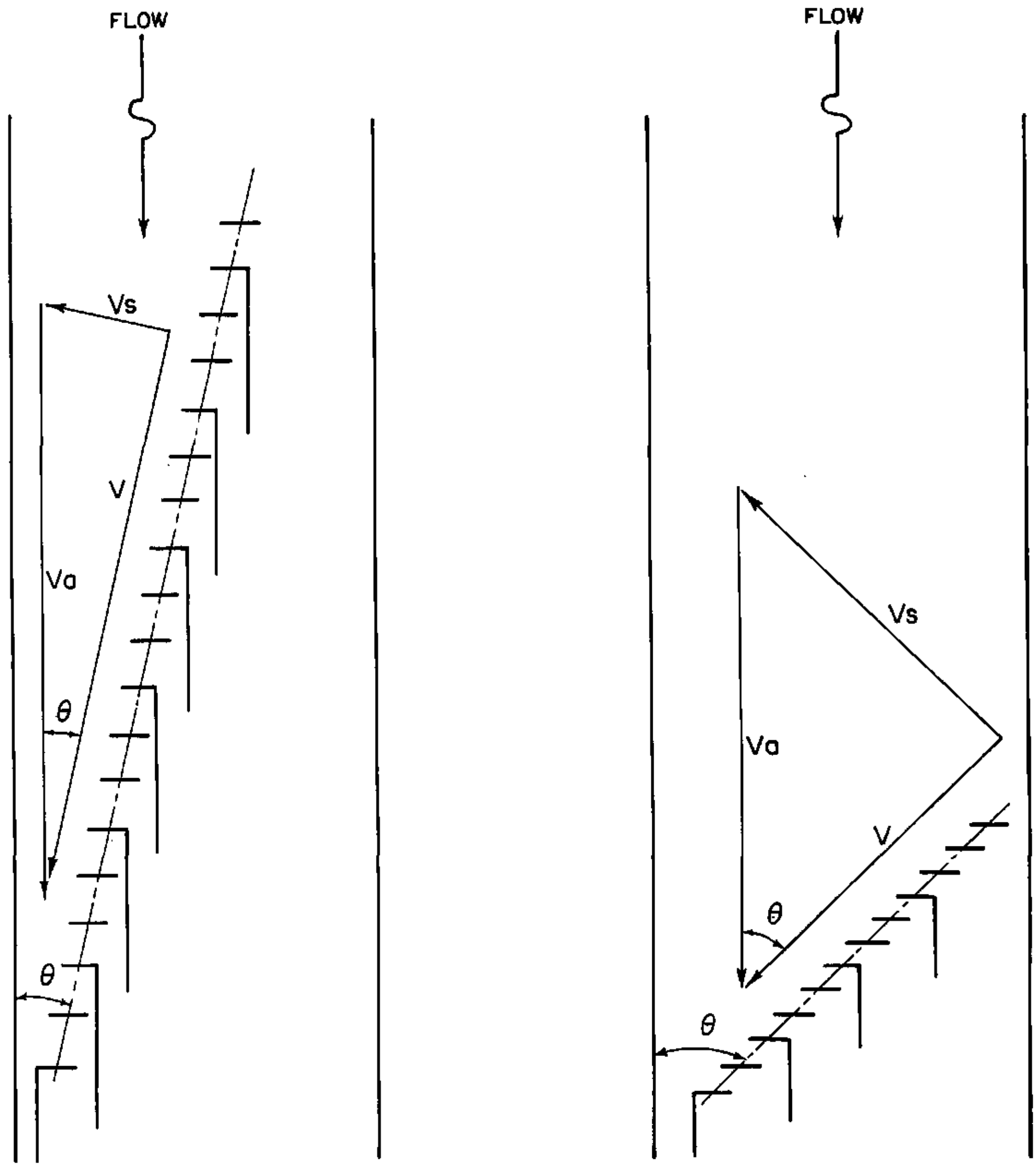
DIAGRAMS ILLUSTRATING REACTION OF FISH TO LOUVERS



(A) When approach velocity exceeds swimming speed of fish.



(B) When approach velocity is under or near the swimming speed of fish.



A
$\theta = 11.5°$

B
$\theta = 45°$

Va = Approach velocity of flow in feet per second
Vs = Swimming speed of fish in feet per second
V = Resultant movement of fish in feet per second
θ = Angle of the line of louvers

DIAGRAMS SHOWING RANGE OF ANGLES IN LINES OF LOUVERS TESTED AND VECTORS OF FORCE IN FLOW AND FISH MOVEMENT

Table 1.--Swimming speed (V_s) required of fish passing line of louvers for given approach velocities (V_a) and selected angles (θ) of the line of louvers. ($V_s = V_a \sin \theta$)

V_a - APPROACH VELOCITY - (Feet Per Second)	8	10	12	14	16	18	20	25	30	35	40	45
7.0	0.97	1.22	1.46	1.69	1.93	2.16	2.39	2.96	3.50	4.02	4.50	4.95
6.5	0.90	1.13	1.35	1.57	1.79	2.01	2.22	2.75	3.25	3.73	4.18	4.60
6.0	0.84	1.04	1.25	1.45	1.65	1.85	2.05	2.54	3.00	3.44	3.86	4.24
5.5	0.77	0.95	1.14	1.33	1.52	1.70	1.88	2.32	2.75	3.15	3.54	3.89
5.0	0.70	0.87	1.04	1.21	1.38	1.53	1.71	2.11	2.50	2.87	3.21	3.54
4.5	0.63	0.78	0.94	1.09	1.24	1.39	1.54	1.90	2.25	2.58	2.89	3.18
4.0	0.56	0.69	0.83	0.97	1.10	1.24	1.37	1.69	2.00	2.29	2.57	2.83
3.5	0.49	0.61	0.73	0.85	0.96	1.08	1.20	1.48	1.75	2.01	2.25	2.47
3.0	0.42	0.52	0.62	0.73	0.83	0.93	1.03	1.27	1.50	1.72	1.93	2.12
2.5	0.35	0.43	0.52	0.60	0.69	0.77	0.85	1.06	1.25	1.43	1.61	1.77
2.0	0.28	0.35	0.42	0.48	0.55	0.62	0.68	0.85	1.00	1.15	1.29	1.41
1.5	0.21	0.26	0.31	0.36	0.41	0.46	0.51	0.63	0.75	0.86	0.96	1.06
1.0	0.14	0.17	0.21	0.24	0.28	0.31	0.34	0.42	0.50	0.57	0.64	0.71

ANGLE OF LINE OF LOUVERS (degrees) θ

the placement of the line of louver slats relative to direction of flow.

Placement of the entire structure relative to direction of flow makes a difference in the way downstream migrants react. They search aimlessly with the structure placed at 90 degrees to flow while with structures positioned under 40 degrees they are guided downstream in their movement.

Individual louver slats are placed 90 degrees to the flow in the Tracy structure although in establishing design criteria trials were also made at 70 degrees and 0 degrees. The 90-degree angle was adopted because it was the most effective in deflecting fish.

The above discussion indicates that young migrants, to maintain their orientation to louvers, particularly under conditions of high velocity, must have fairly smooth flow conditions. Upwelling of water and turbulence readily displaces them from normal orientation and from normal reaction to the louvers. Accumulations of debris may also cause disorientation. Problems relative to both are discussed later in this chapter and also in Chapter V.

One of the most critical areas within the entire louver facility is the entranceway into the bypasses. If velocity increases on entering the bypasses, fish will drift in without hesitation but, if it decreases, fish sense the reduction in velocity and swim back upstream along the line of louvers.

Influence of Day and Night on Fish Deflection

Notwithstanding the many experiments, as well as observations made by the biologists and engineers, there is still little to indicate why louvers are generally more efficient fish deflectors during the night than during the daytime. Even when the louver area was completely darkened by a covering of tarpaulins during daytime deflection, efficiencies never reached the same peak as during the nights. It might be assumed that through greater visibility, daytime efficiencies would be higher; however, due to the extreme turbidity, visibility could not be considered much of a factor even during the daytime. In earlier observations it was noted that young migrants tend to travel after dark, and it can be said that there is definitely a holdup or hesitancy to move as freely in the daytime as at night. This was particularly noticeable in earlier studies within the test flume. Fish released during the daytime would often swim upstream to the head of the flume and remain there until dark. By contrast, fish released within the flume during the night, almost without exception, immediately moved downstream.

Observations on Behavior and Swimming Speeds of Fish

Young striped bass just hatched and measuring about a third of an inch display typical reaction when approaching a louver structure in flows where the velocity of approach is higher than their swimming speed. The fish, when one to three feet away, position themselves at approximately right angles to the line of louvers--the same position assumed by larger downstream migrant salmon and striped bass under similar conditions.

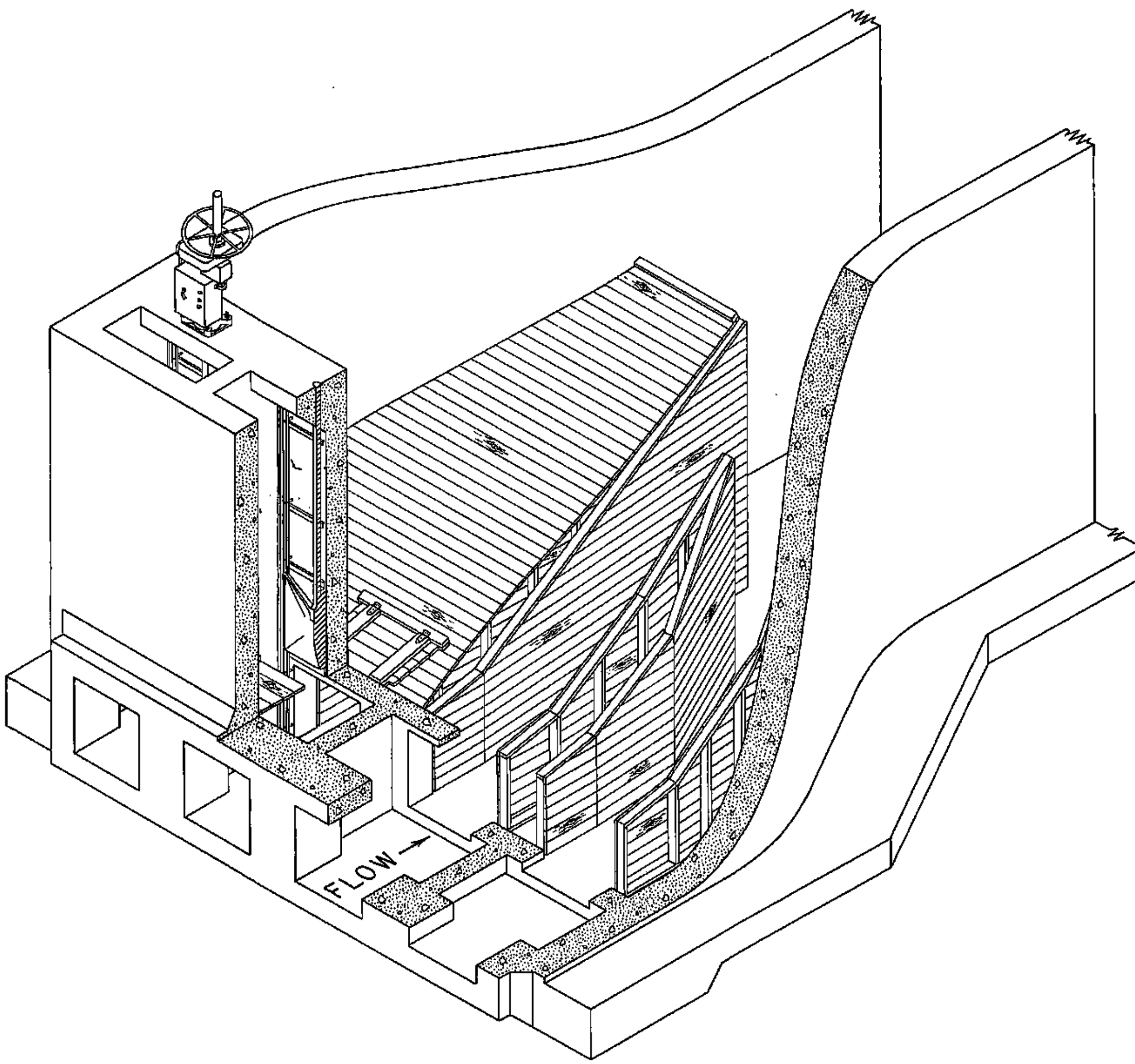
From general observation swimming speeds of king salmon and striped bass appeared to be similar; therefore, swimming speed is not considered a significant factor in efficiency of collection as between the two species. Steelhead trout obtained from the California Department of Fish and Game for experimental purposes displayed a capability of swimming against velocities which would have swept striped bass and king salmon of similar size immediately downstream.

Predation at Bypass Entrances

Predation was not studied at Tracy, but it is assumed that it exists and that it ultimately should be evaluated. At other similar installations predators have been observed maintaining a position directly in front of the bypasses. When predators frighten young fish and disrupt their swimming pattern, loss through the louvers undoubtedly occurs. It may be that at Tracy the trash rack, with only 2-inch spacing between the bars, serves as an obstacle to the entry of large fish and therefore reduces predation. This possibility is suggested by the fact that very few large fish are collected in the operation of the fish collecting facility.

Turbulence in Secondary Channel

One obvious adverse condition was evident shortly after the Tracy facility was placed in operation in February 1957. A considerable rollback of water was observed at the point of discharge into the secondary channel. A turbulent condition from this point carried down to the upstream face of the secondary line of louvers. Fish could be seen swimming in the reverse flow, but apparently they could not find the downstream current. Many of them died, presumably from overexertion. Others passed through louvers either from weakness or disorientation. The Bureau of Reclamation installed wooden baffles and diffusers (Figure 8) as a temporary measure to reduce this turbulence. This partial correction of the turbulent condition resulted in reduction of fish mortality and greatly reduced loss through the secondary louvers.



TEMPORARY INSTALLATION TO DECREASE TURBULENCE

CHAPTER IV

LOUVER TESTING METHODS AND RESULTS

Factors Limiting Testing

Effort was concentrated throughout 1957, the first season, on seeking techniques that could be employed to measure the efficiency of the primary louver system. Basically, all that was required to evaluate louver efficiency was to know the numbers of fish recovered in the holding tanks and the numbers escaping through the louvers during the same period of time. Determining the numbers of fish moving into the holding tanks was simple, requiring only a mechanical operation. The difficult problem was in determining the numbers escaping through the primary louver structure. At Tracy the water is very turbid and varies in depth from 21 to 26 feet. The canal is 84 feet wide, has a flow velocity ranging from zero to 3.9 feet per second, and has up to a 7-foot tidal range. At times it carries great numbers of young food and game fish, many measuring less than an inch in length. The water is turbid with vast amounts of minute peat fibers carried in suspension. These fibers and the frequent high flow velocity made fishing with nets difficult.

Four methods for measuring louver efficiency were considered initially: 1) screening the entire flow below the louver structure to recover all fish passing through, 2) releasing known numbers of marked fish above the primary louvers and counting recoveries, 3) releasing large numbers of unmarked fish above the primary louvers and counting recoveries, and 4) screening sample portions of the flow in the canal both above and below the primary louvers, and all of the flow in the four primary bypasses. These are discussed in greater detail below.

Screening Entire Flow

The first proposed method, i.e. screening the entire flow in the channel below the primary louvers was discarded as impractical because of the large volume of water (5,000 cubic feet per second), relatively high velocities (maximum of 3.9 feet per second), vast amount of peat fibers carried in the flow, and the magnitude of the area which would have to be netted. It was decided instead to seek a technique which would sample a portion of the total canal flow.

Recovery of Marked Fish

The first detailed efficiency evaluation plan, one involving the use of marked fish, was suggested by the Biometrics Unit of the Bureau of Commercial Fisheries. Because problems in marking and recovery techniques remained to be solved, and certain assumptions involved in the use of marked fish needed to be validated, it was decided that the marking studies should be sequential in that the results of one trial would determine what the next trial or action should be.

The first series of marking studies called for the release of a known number of marked fish upstream from the line of louvers for recovery in the holding tanks. Efficiency was to be measured by dividing the number of marked fish recovered in the holding tanks by the number of marked fish released above the primary louvers. In employing this procedure the following assumptions were made:

1. That marked fish would move downstream.
2. That the marks would remain visible for the time required for all fish of a marked lot to be recovered and identified in the holding tank.

3. That holding and marking would cause no mortality or that mortality would be a constant with respect to loss and recovery.
4. That a marked fish is as likely as an unmarked fish to be recovered.
5. That the distribution of marked fish within the total flow is the same as that of unmarked fish.
6. That if efficiency is independent of depth, then assumption 5 may be replaced by the assumption that all sections of the louver system fish with equal efficiency.

Recovery of King Salmon Marked by Fin Clipping

About 3-inch long fish were marked by clipping their fins. To determine their rate of travel from the primary bypasses to the holding tanks, they were released into the four primary bypasses in the order of bypass numbers 4, 3, 2, and 1 (Figure 9). Before being released the fin-clipped fish were held overnight for conditioning.

In the testing process, fish and water were poured into a large funnel leading into a 4-inch rubber tube that reached 8 feet back into each bypass to a depth of 3 feet. Compressed air was used to force fish and water out of the lower end of the tube. Water velocity in the bypasses at the time of release was approximately 2.6 feet per second.

Continuous collections were made in holding tanks 1 and 2 alternating every 15 minutes and continuing for 2 hours after the last release was made.

It was found that even though all of the fish passed readily into and through the primary bypasses, approximately 20 percent were not recovered in the holding tanks. Subsequent draining of the secondary system canal revealed many marked salmon had remained above the louvers.

Waiting for the fish to move would have introduced many complications both practically and statistically. Therefore the use of fin-clipped fish to evaluate the efficiency of the primary louver was abandoned. Data from this series of tests are given in Figure 10.

Marking Striped Bass with Dyes

As small-sized striped bass, one-third to three-fifths of an inch in length, could not be marked by fin-clipping, other suitable means for identifying them were sought, among them the use of dyes and colored latex. Different dyes used in various concentrations included Gentian Violet, Carbo-Fuchsin, Brilliant Vital Red, Malachite Green, Evans Blue, and red, yellow, and green food colors. Liquid latex was diluted for subcutaneous injections in different areas. Unfortunately, use of the dyes proved infeasible because their affinity for the mucous covering of the fish lasted no longer than ten minutes--insufficient for test purposes.

In handling the fish for marking and also for other purposes, tricaine methanesulfonate (MS222) proved to be a very effective sedative. Sodium amytal was found ineffective for striped bass. Water was aerated as required and salt added in some instances when treating striped bass to hold them in the best possible physical condition prior to test periods.

Release and Recovery of Unmarked Fish

Following the unsuccessful attempts to develop a marking technique for small striped bass, another procedure referred to as "unmarked release-recovery" was tried. While statistically adequate this plan failed in practice. It called for the release of a large known number of young, unmarked striped bass (N_1) just above the

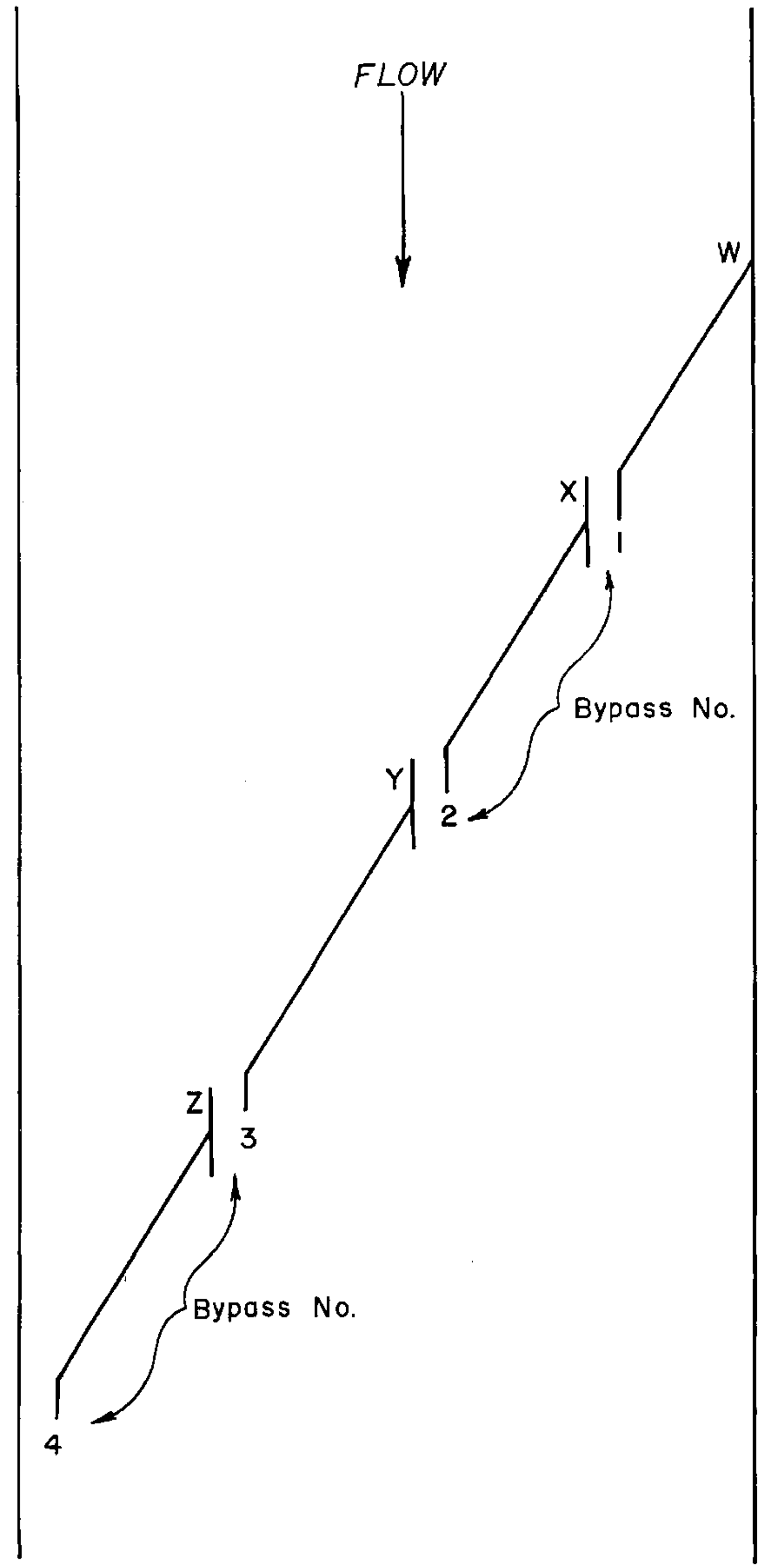
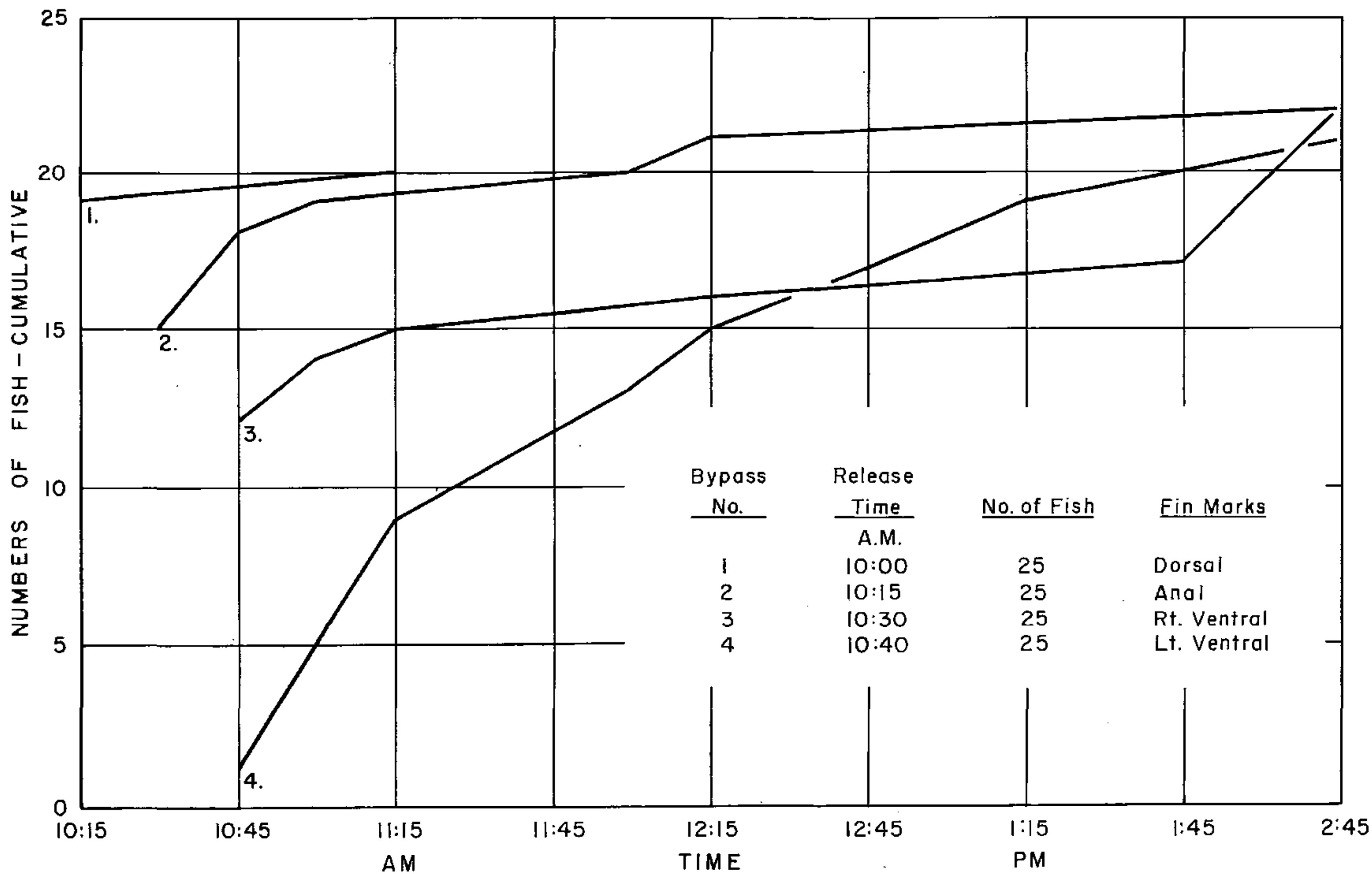


DIAGRAM OF TRACY LOUVER ARRANGEMENT



TRAVEL TIME OF MARKED KING SALMON
BETWEEN PRIMARY BYPASSES AND HOLDING TANKS

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Fig. 10

primary louvers during the daytime when migration is normally lowest. It was hoped that the recapture of a large number of released fish, C_1, would stand out in strong contrast to the smaller number normally passing through the system during this period. By estimating the number of striped bass normally caught, C_2, during this period, a measure of the efficiency of the primary, P, could be theoretically determined by subtracting C_2 from the total catch, C_T, where $C_T = C_1 + C_2$, and dividing by the total number of fish released, N_1:

$$P = \frac{C_T - C_2}{N_1}$$

In arriving at the numbers of migrants normally caught (C_2) for any specific time period, primary bypass nets were to be fished for a series of 3 consecutive equal (10-minute) periods until sufficient data were available to allow for an estimate of the catch of the second or mid-period for any specific series. After this estimate had been made, release of the young, unmarked migrants could be made during the mid-period.

Additionally, to collect fish in the best possible condition, a 17-foot net in the form of a tube was led from No. 3 bypass into a large, screened livetank. This equipment could be operated for only about 30 minutes. By that time, it was inoperable due to complete clogging by debris, mostly peat fibers.

The fish available were mostly striped bass about an inch to an inch and a quarter in total length. These were used in the "unmarked release-recovery" method. First attempts to handle these fish resulted in mortalities of about 80 percent which was considered excessive. By anesthetizing the fish with tricaine methanesulfonate (MS222, 14 Gms. to 50 gallons of water) prior to handling, the mortality was reduced to 20 to 35 percent.

Because the number of fish present was lowest during daylight hours, the number released for recovery was relatively large. Recovery, however, was very low. This could have been due to holdup in the secondary channel and loss through the louvers, likely because of the impaired physical condition of the fish caused by handling. Because of these uncertainties, this method did not seem sufficiently conclusive as to results.

Screening a Portion of Total Canal Flow

To avoid the mortalities caused by handling the following method was tried as an alternative. Simultaneous collections of striped bass were made using 12 fyke nets. Four of these with openings measuring 4 feet by 4 feet, straining a total of approximately 4 percent of the average channel flow, were fished at forebay (i.e. above the primary louvers) stations equidistant across the 84-foot channel on a line beginning 12 feet upstream from the first louver slat. Four similar nets were fished at afterbay stations (below the louvers) directly downstream from the forebay nets and next to the downstream edge of the primary louver deck. The remaining four nets fished the discharge from the bypasses into the secondary. The procedure in fishing the nets was to set them in sequence at 3-minute intervals and to raise them in the same order as they were set. With 8 nets (4 above and 4 below the louvers) each net fished a 24-minute period. The nets collecting fish diverted by the four bypasses were fished for 12-minutes at midtime between setting the first net in the primary channel and removing the last one.

For the purposes of this test it was assumed that all nets fished with equal efficiency, that lateral movement of fish induced by the louvers did not affect collection and that fish do not move through the louvers in significant numbers when velocities drop below one foot per second. A direct comparison was made of the catches in the two sets of nets fishing the primary channel. As shown in Table 2, the forebay nets caught 274 striped bass and the afterbay nets, which were aligned directly downstream from those ahead, caught 8 striped bass. Thus the nets ahead took 97.2 percent of the total catch of all of the nets. Because this method sampled only 4% of the flow and because larger fish might avoid entering the nets, the findings in this case were considered indicative but not conclusive.

Screening Total Flow into Secondary Channel

Nets were set to fish each of the four bypasses from the primary louver system at the point of discharge into the secondary channel. These strained the total flow into the secondary. The numbers of fish collected by these nets represents the total number of fish diverted by the primary louvers. Numbers of striped bass caught with these nets together with those above and below the primary louver system are shown in Table 2.

Based on the data for flows of 2.5 feet per second, the four forebay nets fishing in the upper 10 feet of water captured an average of 38 striped bass per hour and the bypass nets an average of 675 per hour. The finding in earlier studies (ibid., 1957, p. 29) on the vertical distribution of small striped bass in the forebay of the canal showed that 72 percent of them occurred in the upper 10 feet of water

Table 2.--Recoveries of Striped Bass with Fyke Nets Fished Above and Below Primary Louvers and at Discharge from Bypasses into Secondary Channel

Tidal Flow	Channel Velocity*	Above Louvers Net No.				Below Louvers Net No.				Bypass Net No.			
		1	2	3	4	1	2	3	4	1	2	3	4
	(f/s)	(Numbers of fish recovered)											
Out	1.4		1		2					5	5	4	23
			2							4	2	2	30
				1								1	22
			1							2			36
										2	2	1	22
		1	1		1					4	2	3	21
Out	1.9			1						12	11	5	19
		3	3	5	6					29	24	24	71
		1			1					6	4	5	32
		2								7	7	16	23
		4			2					5	5	11	31
										3	6	8	34
				3	5					3	2	5	55
In	2.5	1	2	1						1	8	5	26
		2		1	1	1				7	14	8	26
		10	11	13	13				1	25	49	65	110
		2	5	3	3					7	10	8	18
				1						7	8	7	14
		17	14	12	5				2	37	52	56	135
		2	3	3	1					8	6	11	23
			1	2						3	9	6	22
		8	11	8	6		1			46	72	63	175
		3	2	5	1					11	17	22	42
				2	2					8	11	11	29
			4	3	6		1			39	62	77	191
			3	2	2					4	15	14	52
In	1.9		3								8	1	17
		1	2	2						1	1	5	20
			3		1					3	5	3	23
				2						3	1		18
			1		3					5	5	4	21
		2			1					4	3	1	29
		1	1		1					4	4	5	13
Out	1:4				1					1	1	5	19
									1	1	1	1	12
			1		2		1			2			11

(Continued)

Table 2.--Recoveries of Striped Bass with Fyke Nets Fished Above and Below Primary Louvers and at Discharge from Bypasses into Secondary Channel (Cont'd)

Tidal Flow	Channel Velocity* (f/s)	Above Louvers Net No. 1	2	3	4	Below Louvers Net No. 1	2	3	4	Bypass Net No. 1	2	3	4
		(Number of fish recovered)											
In	1.4									1	1		7
										2			11
		1	1							4	4	1	8
										1			3
Out	0.8									2	1	2	5
													3
					1								4
												1	
Column Totals		61	76	70	67	1	3	0	4	319	438	467	1506
Grand Totals			274								2730		
Proportion of fish recovered from each bypass (Percent)										12	16	17	55

* $\pm$ 0.2 feet per second.

and 28 percent of them in the lower 10 feet of water. On this basis, with 38 fish being caught in the upper 10 feet where 72 percent of the fish occur, it can be estimated that four nets fishing in the lower 10 feet of water would have taken an average 15 fish per hour or 28 percent of the total. All eight nets would have fished 8 percent of the total flow for a total of 53 fish. Therefore, the estimated total number of fish passing down the entire canal would be an average of 663 per hour derived thus:

$$8:53 = 100:X$$
$$8X = 5300$$
$$x = 662.5$$

This compares with the actual total catch in the bypasses of 675, which would indicate that close to 100 percent of the fish were deflected by the primary louver system. The Advisory Council concluded, however, that because this finding was, in part, hypothetical it could not be considered conclusive and that other means of measurement should be tried in 1958.

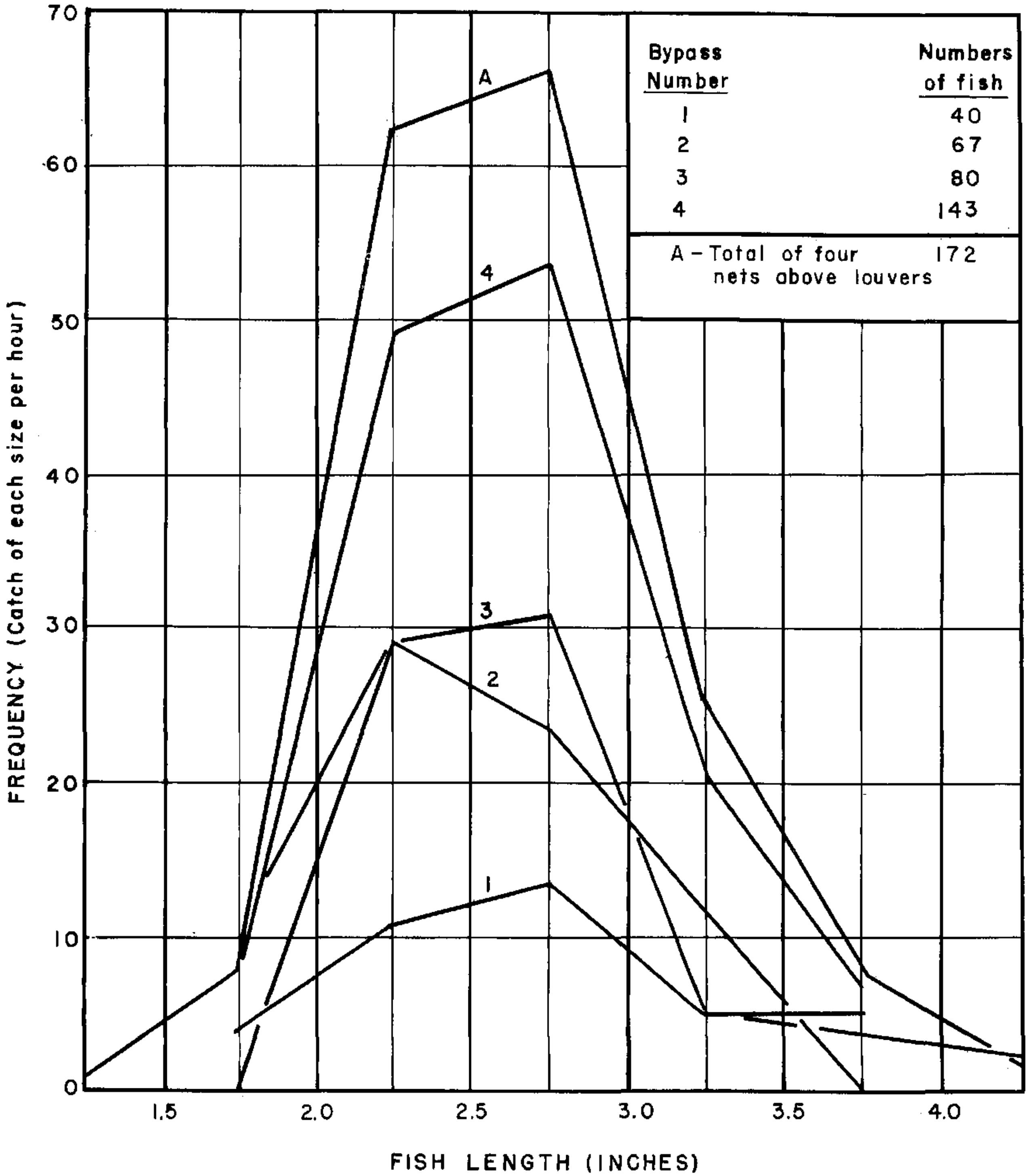
Effect of Tides, Time of Day, and Velocity on Fish

During the course of the 1957 tests several factors that play a part in the overall efficiency of the louver system were investigated. These include information on the relative percentage of fish entering each of the four primary bypasses, selectivity of the bypasses and the nets as to size of fish collected, and the effect of tides on the numbers of fish entering the canal and passing into the primary bypasses.

Table 3 shows that if velocity increases, the proportion of striped bass moving into the first three bypasses also increases.

Figure 11 shows that there was evidently no selectivity in

Fig. 1-1



SIZES OF STRIPED BASS RECOVERED WITH FYKE NETS ABOVE LOUVERS AND FROM BYPASSES

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the sizes of fish collected by either the primary bypasses or by the nets fishing in the primary canal.

During several nights the total bypass flows were fished during the incoming tide for periods of 12 minutes after which the catch was enumerated. Figure 12 indicates that the greatest numbers enter the canal and the bypasses shortly after high low tide.

Table 3.--Percent of Striped Bass Collected in Bypasses at Three Channel Velocities

Bypass Number	Velocities		
	1.4 feet per second (percent)	1.9 feet per second (percent)	2.5 feet per second (percent)
1	9	14	12
2	6	13	19
3	6	16	20
4	79	57	49

Evaluation of 1957 Testing Program

On December 13, 1957, members of the Advisory Council met at Tracy, California to review the results of the season's work. Since all of the methods tried had limitations which left the findings open to question a new program for measuring the efficiency of the primary louver system was suggested by the Biometrics Unit of the Bureau of Commercial Fisheries at Seattle, Washington (Appendix C).

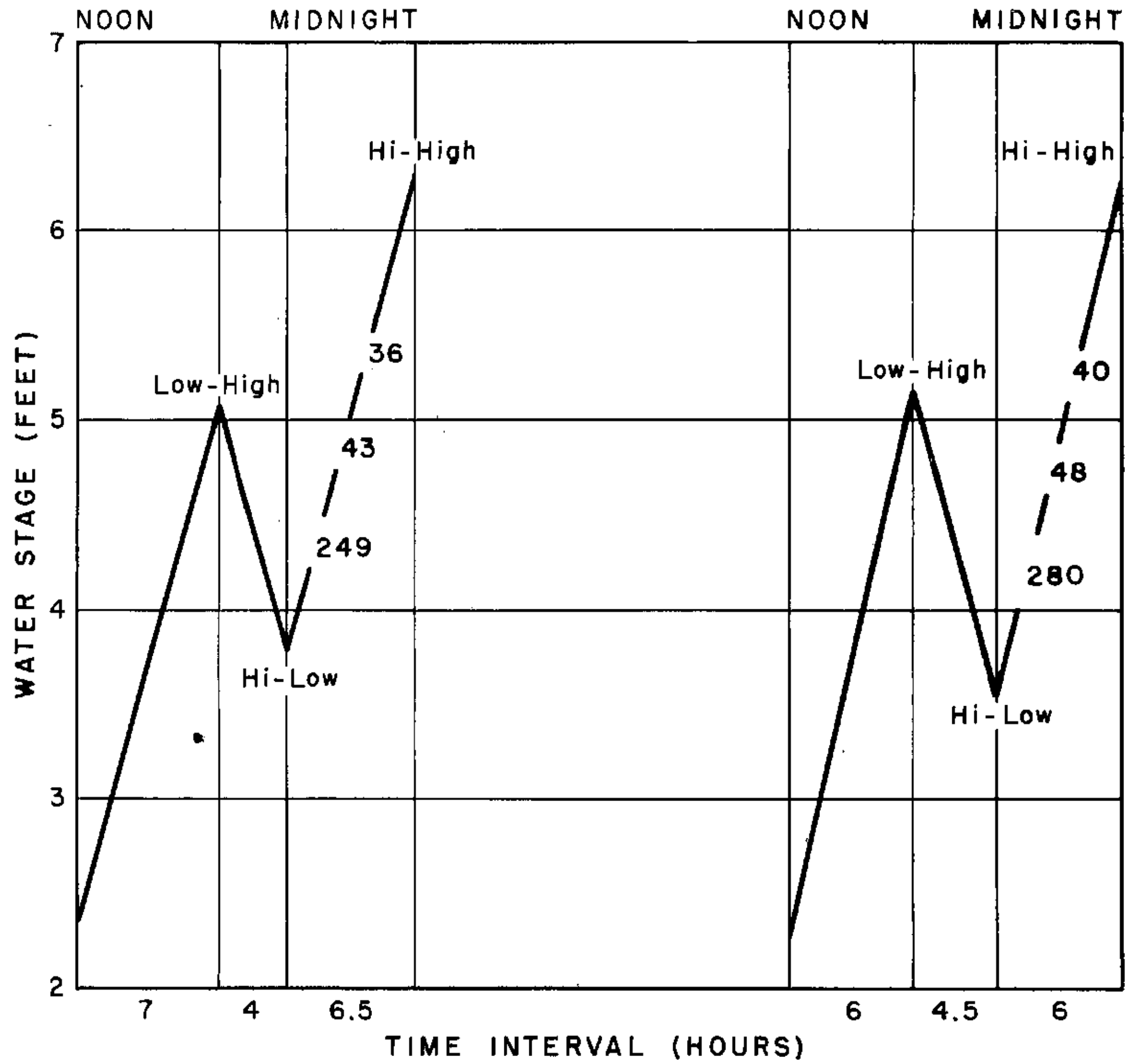
This program was discussed at some length, particularly the mechanics of fishing nine fyke nets at each of two locations. The requirement that these be fished as nearly simultaneously as possible posed difficult mechanical problems and involved costs far in excess of those originally estimated.

At a second meeting on February 14, 1958, the Fish and Wildlife Service representatives advised that even if the funds were available the facilities and equipment for this program could not be completed by July 1, 1958. This meant that testing of the primary structure would have to be deferred until at least 1959 by which time the inter-bureau agreement for the program would have expired. As an alternative the suggestion was made that the deflecting efficiency of the secondary louver system (Figure 13) be tested during the balance of 1958 and that the results be applied to the primary system. In support of this suggestion it was pointed out that the two louver structures are similar in design, in function and in operation, and that in the secondary all of the water could be sampled. Diversion through the bypass fishways leading from the primary to the secondary louvers and the excitement and disorientation resulting from ejection into the turbulence of the secondary were considered as adverse factors. If fish were diverted by the secondary system in spite of these conditions then, it was reasoned, they would be even more likely to be diverted in the primary where these conditions were absent. That being the case, the application of the findings in the secondary to the primary would be on the conservative side.

In further support of the suggestion that testing be done in the secondary it was recalled that tests had been made under somewhat similar circumstances in Bay No. 1 of the pilot structure (ibid., 1957, pp. 64-75) with which findings could be compared. The arguments favoring use of the secondary louvers were accepted and the 1958 testing plan established accordingly.

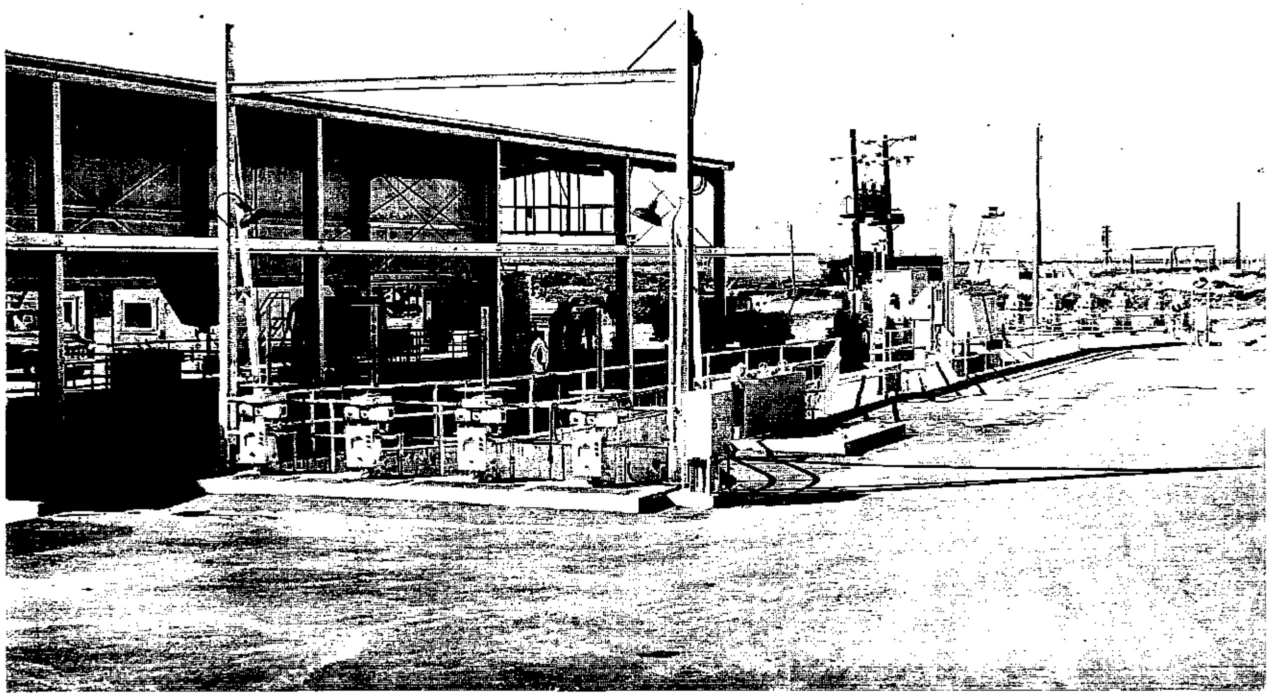
Use of Secondary Louvers in 1958 Test Program

Testing in the secondary louver system was unavoidably delayed until July 1958 due to the small volume of water drawn by the Tracy Pumping Plant up to that date. With only a single pump operating during the



VARIATION IN CATCHES IN PRIMARY BYPASSES DURING INCOMING TIDE

(NUMBERS OF FISH CAUGHT SHOWN BY NUMBERS ON CURVES)



Secondary Louver System

Fig. 13

first part of the season, fish did not enter in sufficient numbers to allow for testing. By the time testing started the king salmon seaward migration was about over and the stripers had grown considerably. This required some testing early in 1959 to complete work on these species.

In using the secondary louver system for determining effectiveness in deflecting fish a series of tests were conducted with fish of different species and lengths. This was done to provide a direct measure of the loss of fish through the louvers under the following conditions:

1. Length and species of fish
2. Daytime and nighttime operation
3. Different ratios of bypass to approach velocities
4. Double and single line of louvers

Because approach velocity in the primary channel is subject to variation, ranging from zero to 4.0 feet per second, and because velocity directly influences the deflecting efficiency of the louvers, tests were conducted with the following approach velocities: 1.0, 1.5, 2.0, 2.5, 3.0 and 3.3 feet per second.

During this period of study 165,000 fish (mostly striped bass and white catfish but with a few king salmon) were handled in 1,074 individual tests. With the youngest striped bass not available during the 1958 migration season, the range and numbers of tests with this species was necessarily limited.

Test procedure in the secondary canal was simple. A large net (Figure 14) 9 feet deep, 8 feet wide, and 16 feet long was constructed with four separate funnels or fykes built into the throat, each leading into a common "pot". The net was hung on a steel frame which in turn was held in position by guide slots. The net was raised or lowered with an electrical hoist. A zipper at the downstream end of the net allowed for inspection of the pot and counting the fish.

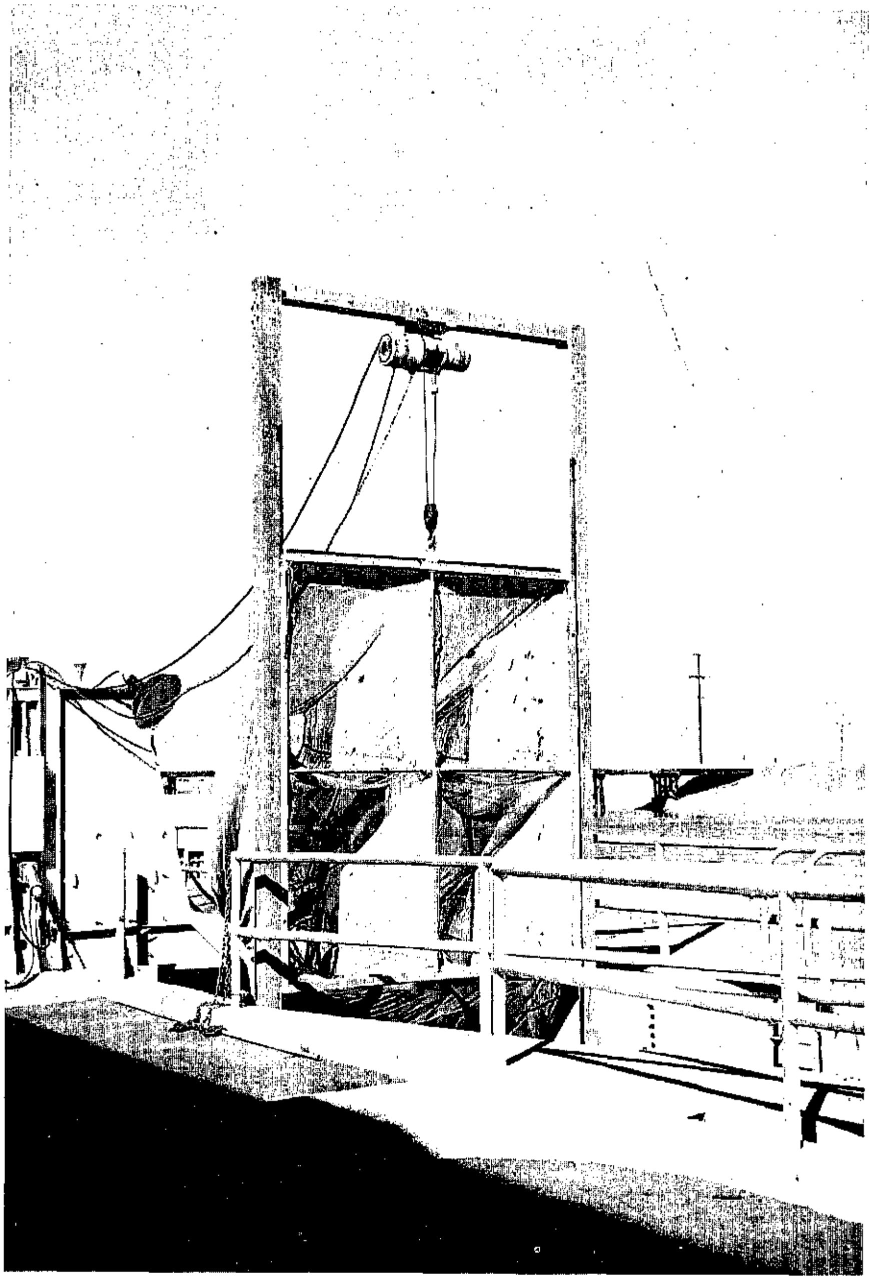
Fishing procedure involved lowering the net to the full canal depth, normally shallower than net height, so that the total canal flow was screened. Simultaneously, bypass flow was discharged into a holding tank. Collection periods were equal for both net and tank, usually 10 minutes.

Length and Species of Fish Recovered

Length of fish is an important consideration particularly with respect to striped bass and white catfish. Large numbers of these fish which had been recently hatched and were as small as a third of an inch entered the area. These small fish as well as others, including king salmon measuring an inch and a half to four inches in length, were used in the tests.

Table 4 shows that the recovery rate of the two size groups of fish available was generally high. Noteworthy is the fact that most (76-86 percent) of the small fish under an inch in length are diverted if the flow is uniform and velocity is below 3 feet per second. At the outset of investigations leading to the construction of the Tracy facilities it had not been considered possible to save significant numbers of such small fish.

The decrease in the proportion of small fish diverted as the approach velocity increased is explained by the fact that in a velocity of 3.0 feet per second, the swimming speed must be 0.8 feet per second to hold a position normal to the louvers and to avoid being swept through them. This is close to the maximum swimming ability of striped bass and white catfish under an inch in length.



Net used to screen flow in secondary canal

Table 4.--Influence of Length of Fish and Approach Velocity on Deflecting Efficiency of Secondary Louvers

Approach Velocity Feet per Second	1.0	1.5	2.0	2.5	3.0	3.3
	Fish Lengths 1/3 inch to 1 inch					
STRIPED BASS						
Number of collections	8	8	12	9	8	
Number of fish collected:						
In net	129	116	185	207	191	
In tank	2,302	1,740	2,166	1,849	1,126	
Efficiency (percent)	94.6	93.7	92.1	89.3	85.5	
WHITE CATFISH						
Number of collections	18	13	17	16	10	
Number of fish collected:						
In net	1,250	1,381	1,737	2,075	1,244	
In tank	7,586	5,002	5,396	6,441	4,205	
Efficiency (percent)	85.8	78.3	75.6	75.6	77.1	
	Fish Lengths 1.5 inch to 4 inches					
STRIPED BASS						
Number of Collections	4	11	4	6	4	4
Number of fish collected:						
In net	10	21	8	13	2	2
In tank	200	385	222	431	285	124
Efficiency (percent)	95.2	94.8	96.5	97.1	99.3	98.4
WHITE CATFISH						
Number of collections	13	15	10	12	9	8
Number of fish collected:						
In net	15	8	20	21	47	8
In tank	5,892	1,602	2,319	2,145	2,244	1,374
Efficiency (percent)	99.7	99.5	99.1	99.0	97.9	99.4
KING SALMON						
Number of collections	13	12	8	6	6	8
Number of fish collected:						
In net	25	6	5	5	7	2
In tank	332	239	264	426	460	213
Efficiency (percent)	92.9	97.5	98.1	98.8	98.5	99.0

Effect of Daylight and Darkness on Fish Recovery

In the course of earlier work 5/ it had been observed that during the hours of darkness deflection efficiencies were generally higher than those prevailing during the daytime. To verify this observation and to secure more precise information, special tests were conducted with striped bass and white catfish.

Tables 5 and 6 summarize the results of these tests. Apparently white catfish are deflected equally well during periods of daylight and darkness. This is evidently not true for striped bass, however. When velocities were less than 2.5 feet per second, efficiency was very high during both daytime and nighttime conditions. Figure 15 shows the average numbers of striped bass collected hourly during four-pump operation, July 23 to 29, 1957, and a five-pump operation, July 12 to 17, 1957.

Effects of Bypass to Channel Velocities on Deflecting Fish

The purpose of investigating the ratio of velocity in the bypasses to the velocity of flow approaching the louvers was to find the ratio most suitable for deflecting fish. It was known in the design of the structure that the velocities in the bypasses should be higher than those approaching the louvers. With the completion of the facility it was possible to verify the initial observation and to determine the effects of various ratios.

Table 7 gives the findings for striped bass under 1.5 inches in length. Generally there was an advantage in using a bypass to approach velocity ratio of 1.4 to 1 rather than 1.0 or 1.2 to 1. For

5/ Field and Laboratory Tests to Develop the Design of a Fish Screen Structure, Delta-Mendota Canal Headworks, Central Valley Project, California. U. S. Department of the Interior, Bureau of Reclamation, Division of Engineering Laboratories, Hyd. Lab. Report No. Hyd.-401, March 21, 1955. Fig. 22.

Table 5.--Efficiency of Secondary Louvers in Deflecting Fish at Various Velocities

DAYTIME

Approach Velocity* Feet Per Second	1.0	1.5	2.0	2.5	3.0
	Fish Lengths 1.5 inch to 3.0 inches				
STRIPED BASS					
Number of collections	4	4	4	4	
Number of fish collected:					
In net	6	11	11	1	
In tank	63	112	242	168	
Efficiency (percent)	91.3	91.0	95.6	99.4	
WHITE CATFISH					
Number of collections	4	4	4	4	4
Number of fish collected:					
In net	4	3	8	1	13
In tank	329	653	1,176	600	649
Efficiency (percent)	98.7	99.5	99.3	99.8	97.9
KING SALMON					
Number of collections	8	8	8	8	8
Number of fish collected:					
In net	37	43	18	0	1
In tank	308	312	310	160	84
Efficiency (percent)	89.2	87.8	94.5	100	98.8

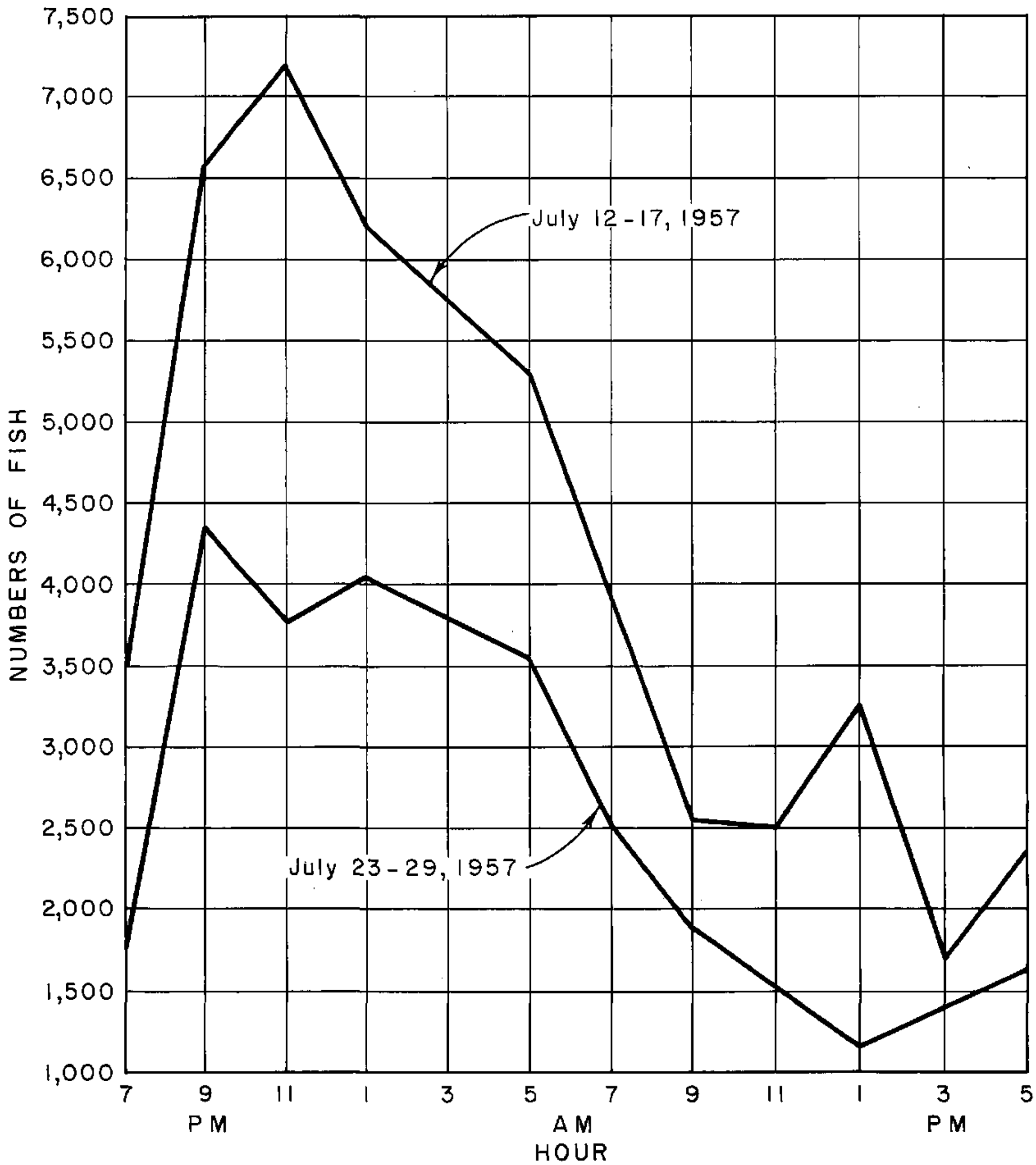
* Average velocity of flow in secondary channel approaching louvers.

Table 6.--Efficiency of Secondary Louvers in Deflecting Fish at Various Velocities

NIGHTTIME

Approach Velocity* Feet per second	1.0	1.5	2.0	2.5	3.0	3.3
	Fish Lengths 1.5 inches to 3.0 inches					
STRIPED BASS						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	7	3	1	3	2	2
In tank	118	95	99	250	285	124
Efficiency (percent)	94.4	96.9	99.0	98.8	99.3	98.4
WHITE CATFISH						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	0	4	5	11	40	6
In tank	137	542	882	1,038	1,865	1,083
Efficiency (percent)	100	99.2	99.4	98.9	97.9	99.4
KING SALMON						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	25	6	5	5	7	2
In tank	332	239	264	426	460	213
Efficiency (percent)	92.9	97.5	98.1	98.8	98.5	99.0

*Average velocity of flow in secondary channel approaching louvers.



STRIPED BASS COLLECTED PER HOUR

Table 7.--Influence of Ratio of Bypass to Channel Velocity and of Different Approach Velocities on Efficiency of Secondary Louvers in Deflecting Fish

Fish Length under 1.5 inches
Bypass-Channel Velocity Ratio 1.0 to 1.0*

Approach Velocity Feet per Second	1.0	1.5	2.0	2.5	3.0
STRIPED BASS					
Number of collections	14	13	14	2	
Number of fish collected:					
In net	251	228	156	47	
In tank	1,784	1,878	1,171	447	
Efficiency (percent)	87.7	89.2	88.2	90.4	
WHITE CATFISH					
Number of collections	14	13	14	2	
Number of fish collected:					
In net	651	601	409	56	
In tank	1,226	1,341	1,937	178	
Efficiency (percent)	65.3	69.1	82.5	76.0	

Fish Length under 1.5 inches
Bypass-Channel Velocity Ratio 1.2 to 1.0*

Approach Velocity Feet per Second	1.0	1.5	2.0	2.5	3.0
STRIPED BASS					
Number of collections	17	13	15	19	2
Number of fish collected:					
In net	233	211	213	482	17
In tank	1,796	1,989	2,504	2,888	104
Efficiency (percent)	88.5	90.4	92.2	85.7	85.9
WHITE CATFISH					
Number of collections	17	13	15	19	2
Number of fish collected:					
In net	1,144	1,052	1,636	2,034	216
In tank	7,233	3,568	3,033	6,414	1,088
Efficiency (percent)	86.3	77.2	65.0	76.0	83.4

(Continued)

Table 7.--Fish Length under 1.5 inches, single louver
Bypass-Channel Velocity Ratio 1.4 to 1.0 (Cont'd)

Approach Velocity Feet per second	1.0	1.5	2.0	2.5	3.0	3.3
STRIPED BASS						
Number of collections	16	14	13	9	8	
Number of fish collected:						
In net	235	201	211	482	454	
In tank	3,552	3,079	2,290	4,094	4,871	
Efficiency (percent)	93.8	93.9	91.6	89.5	91.4	
WHITE CATFISH						
Number of collections	10	14	13	9	8	
Number of fish collected:						
In net	459	1,242	489	619	1,028	
In tank	1,280	4,348	1,674	2,502	3,117	
Efficiency (percent)	73.6	77.8	78.4	80.1	75.2	

Fish Length 1.5 to 3.0 inches, double louver
Bypass-Channel Velocity Ratio 1.2 to 1.0

Approach Velocity Feet per second	1.0	1.5	2.0	2.5	3.0	3.3
STRIPED BASS						
Number of collections	7	10	8	4		
Number of fish collected:						
In net	25	57	53	29		
In tank	319	661	401	222		
Efficiency (percent)	92.7	92.0	88.3	88.4		
KING SALMON						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	35	24	13	2	5	0
In tank	382	287	297	176	175	89
Efficiency (percent)	91.6	92.2	95.8	98.8	96.1	100.0
WHITE CATFISH						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	11	1	6	9	7	2
In tank	5,636	946	971	507	349	291
Efficiency (percent)	99.8	99.8	99.3	98.2	98.1	99.3

(Continued)

Table 7.--Fish Length 1.5 to 3.0 inches, double louver
Bypass-Channel Velocity Ratio 1.4 to 1.0 (Cont'd)

Approach Velocity Feet per second	1.0	1.5	2.0	2.5	3.0	3.3
STRIPED BASS						
Number of collections	4	11	4	6		
Number of fish collected:						
In net	10	21	8	13		
In tank	200	385	222	431		
Efficiency (percent)	95.2	94.8	96.5	97.1		
KING SALMON						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	7	3	1	3	2	2
In tank	118	95	99	250	285	124
Efficiency (percent)	94.0	97.0	99.0	99.0	99.3	98.0
WHITE CATFISH						
Number of collections	8	8	8	8	8	8
Number of fish collected:						
In net	0	4	5	11	40	6
In tank	137	542	882	1,038	1,865	1,083
Efficiency (percent)	100.0	99.3	99.4	99.0	98.0	99.5

*Nighttime tests.

striped bass and king salmon over 1.5 inches in length, the deflection efficiencies were also generally higher when the bypass to approach velocity ratio was 1.4 to 1.0.

For white catfish under 1.5 inches in length, bypass to approach ratios of 1.2 to 1.0 and 1.4 to 1.0 gave similar efficiencies. Efficiency was reduced when the ratio was 1.0 to 1.0.

As the minimum length of king salmon available at Tracy was approximately 1.5 inches, all data for this species are for fish of that size or larger. A slightly higher efficiency was obtained for salmon at a bypass to approach ratio of 1.4 to 1.0 than at a ratio of 1.2 to 1.0.

Deflection efficiencies for white catfish over 1.5 inches in length were high at both the 1.2 to 1.0 and the 1.4 to 1.0 ratio.

Comparative Efficiency of Double and Single Lines of Louvers

In earlier studies within a test flume (ibid., 1957, p. 75) it was found that a double line of louvers was somewhat more efficient than a single line. Because of the restricted approach distance in the secondary channel a double louver line was installed. To check whether the findings in the test flume were true for the prototype, tests were started early in the summer of 1958 using striped bass and white catfish under 1 inch in length. By autumn striped bass were more than 1.5 inches long, growth having been very rapid during the summer months. Development of white catfish is slower. Tests with larger catfish were therefore delayed until the early spring of 1959. Table 8 records the results of all tests. With the smaller fish, the double louver line was more efficient at all approach velocities while there was only a slightly better deflection efficiency for the larger

Table 8.--Efficiency of Double Versus Single Lines of Louvers at Various Approach Velocities in Secondary Channel

Fish Length under 1 inch, double louver

Approach Velocity Feet per second	1.0	1.5	2.0	2.5	3.0
STRIPED BASS					
Number of collections	18	13	17	16	10
Number of fish collected:					
In net	193	147	218	456	208
In tank	2,701	2,086	2,516	3,085	1,230
Efficiency (percent)	93.0	93.0	92.0	87.0	85.0
WHITE CATFISH					
Number of collections	18	13	17	16	10
Number of fish collected:					
In net	1,250	1,381	1,737	2,075	1,244
In tank	7,586	5,002	5,396	6,441	4,205
Efficiency (percent)	85.0	78.0	75.0	75.0	77.0

Fish Length under 1 inch, single louver

STRIPED BASS				
Number of collections	15	14	19	12
Number of fish collected:				
In net	275	265	324	233
In tank	2,647	2,982	4,171	1,652
Efficiency (percent)	90.0	91.0	92.0	87.0
WHITE CATFISH				
Number of collections	15	14	19	12
Number of fish collected:				
In net	856	913	1,098	578
In tank	2,682	2,914	2,677	2,475
Efficiency (percent)	75.0	76.0	70.0	81.0

Continued

Table 8.--Efficiency of Double Versus Single Lines of Louver at Various Approach Velocities in Secondary Channel (Cont'd)

Fish length 1.5 to 3.0 inches, double louver

Approach Velocity Feet per second	1.0	1.5	2.0	2.5
STRIPED BASS				
Number of collections	4	11	4	6
Number of Fish collected:				
In net	10	21	8	13
In tank	200	385	222	431
Efficiency (percent)	95.2	94.8	96.5	97.1
WHITE CATFISH				
Number of collections	4	11	4	6
Number of fish collected:				
In net	0	4	5	11
In tank	137	542	882	1,038
Efficiency (percent)	100	99.2	99.4	98.9

Fish length 1.5 to 3.0 inches, single louver

STRIPED BASS			
Number of collections	10	11	7
Number of fish collected:			
In net	11	14	18
In tank	264	253	255
Efficiency (percent)	96.0	94.7	93.4
WHITE CATFISH			
Number of collections	10	11	7
Number of fish collected:			
In net	39	36	26
In tank	281	328	668
Efficiency (percent)	87.0	90.0	96.2

striped bass with the double line. The large white catfish were deflected more efficiently with the double louver line, but at an approach velocity of 1.5 and 2.0 feet per second even the single louver line deflected at least 90 percent of the fish.

CHAPTER V

TRASH REMOVAL AND HOLDING, COUNTING, AND TRANSPORTING FISH

General Observations

In this chapter the operation and effect on efficiency of appurtenant facilities, including trashrack and rake, fish holding tanks, fish hauling buckets, fish sampling equipment, and tank trucks are discussed. Modifications in the design of some of the appurtenant facilities are described, and suggestions are made concerning procedures for operating some of the equipment.

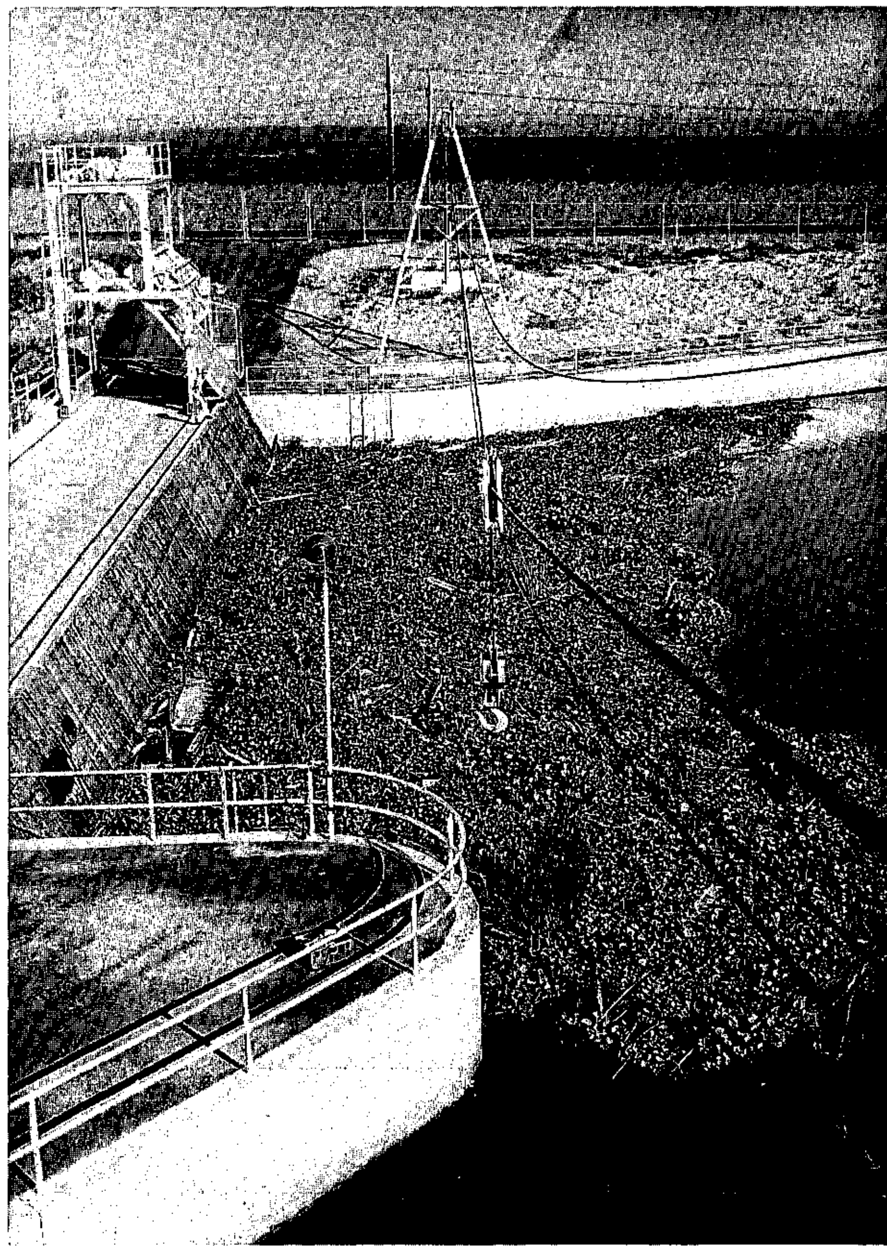
The efficiency of these facilities was studied largely by observation, but many tests were conducted to determine tolerable ranges in water temperature and dissolved oxygen content when confining the several species and sizes of fish in the holding tanks and tank trucks.

Water-borne debris strongly affects louver efficiency. At certain times tremendous volumes of trash are carried in the water drawn toward the Tracy Pumping Plant and deposited onto the trashracks (Figure 11). Some of this debris was washed through the trash bars or pushed through during the cleaning process. In turn, the trash was carried into the bypasses in such quantities as to clog portions of them. This clogging changes the velocity, and young migrants along the louvers and near the bypasses are interrupted in their progress at the point of clogging. Their reaction is to swim away. By suddenly changing their normal movement there is a strong possibility of their being swept through the louvers. For this reason, it is necessary that the bypasses be clear of trash at all times. Observation has indicated that trash against the louvers themselves does not affect the movement of downstream migrants.

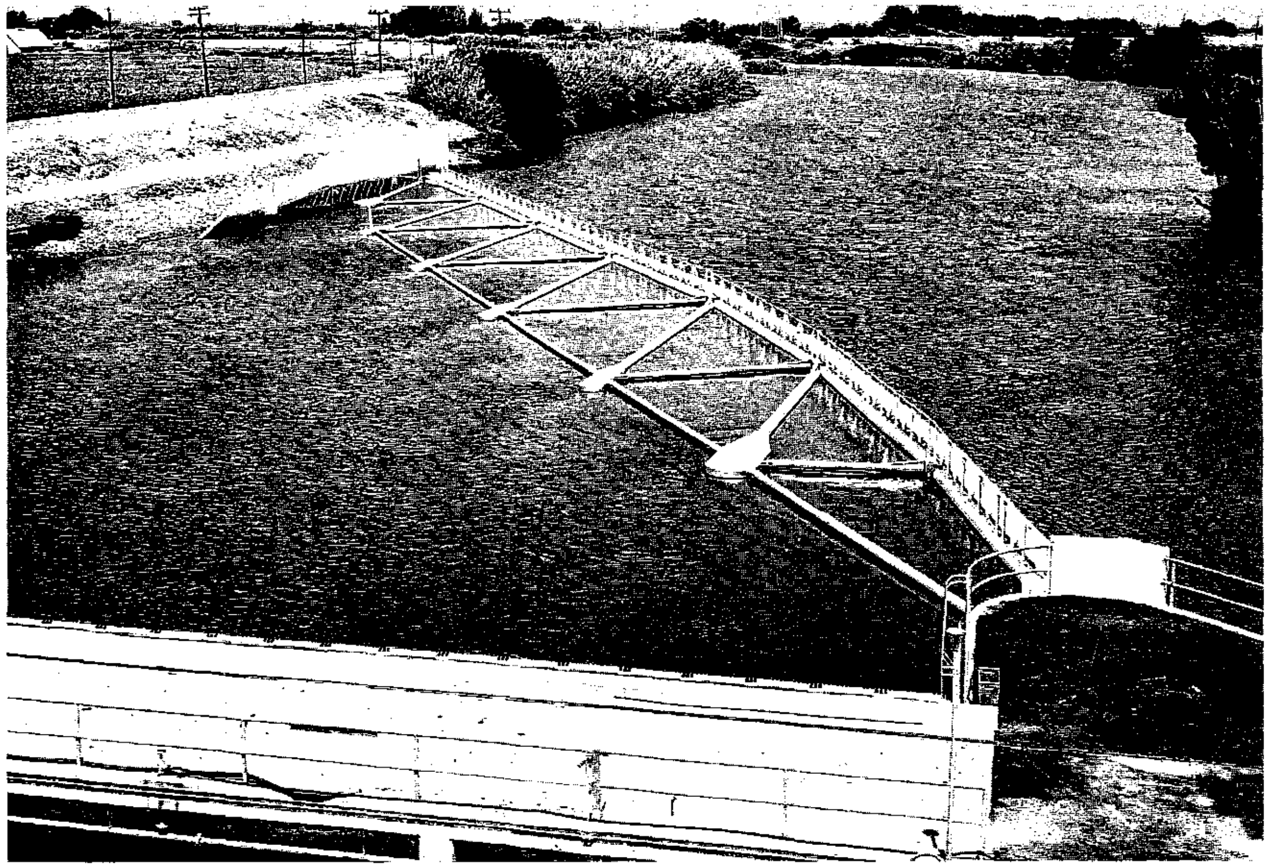
Trash Removal

The trashracks immediately upstream from the primary louver structure have 2-1/8-inch clear openings and are set on a 6 to 12 slope. The trash rake, designed to remove debris from the rack, lacked capacity to handle the large quantities which accumulated, approximately 90% of which is floating material. In 1958 and 1959 it was necessary at times to supplement the rake with a dragline. During the height of the season, late July and August, water hyacinth occurred in such quantities that twenty-four hour operation of both the trash rake and the dragline was necessary. In the process of removal some hyacinth and some tules were broken up and pushed through the rack during cleaning. This fragmented debris passed through the rack in such quantities that the louvers and bypasses of both the primary and secondary systems were sometimes partially clogged. Daily cleaning was often necessary.

To correct this condition, the Bureau of Reclamation designed and constructed a floating boom and conveyor (Figure 16a). The floating boom is placed just ahead of the trashrack and angled toward the conveyor belt (conveyor belt not visible in Figure 16a). A smooth metal facing extends two feet into the water facilitating movement of debris toward the juncture of the boom and canal wall. At this point the conveyor picks up the debris and lifts it into a waiting truck. Not only is debris removal greatly simplified but washing through the trash rack bars is greatly reduced. Only weekly or tri-monthly cleaning of the primary louvers and bypasses is required now rather than daily cleaning as with the original trash rake.



Accumulation of debris at trashrack



Trash deflector above trash rack

Fig. 16a

Operation of Fish Holding Tanks

Fish are collected in four concrete fish holding tanks housed under a metal shelter (Figure 17). Each tank is designed to collect fish until a truck load has accumulated or to hold fish until they can be removed. All four are identical, measuring 20 feet in diameter, with 15-1/2-foot high side walls, and with conical bottoms to assist in flushing fish out and into the lifting bucket. Water from the secondary louver bypass enters a holding tank tangentially through a 20-inch, cast-iron influent pipe.

The fish are retained in the holding tank by the 7-foot, 10-inch diameter by 12-foot high screen that surrounds the fish-lift bucket well. This screen consists of a circular steel frame covered by 5-mesh-to-the-inch, galvanized wire cloth made from 0.092-inch diameter wire, which gives the maximum size opening and yet retains the small fish. The screen rests on a steel seat that surrounds the fish-lift bucket well. The bottom of the screen assembly is formed with a nine-inch steel band with rubber gasket which retains 500 gallons of water in the bottom of the tank. To drain this water, which contains the fish, into the fish-lift bucket the screen is raised 4 inches by air cylinders attached to the "H" beam screen supports above the top of the holding tank.

Depending on the tidal stage, which can vary to an extreme range of 11 feet, each tank holds from 9,500 to 35,000 gallons of water. At a water stage of +3 feet the tank holds a total of 16,500 gallons of which 2,500 is contained within the cylindrical screen area and 14,000 gallons outside, in which the fish are held.

The capacity of the 1,000-gallon tank trucks determines the number of fish which can be held. There is no means of removing part of the fish from a tank. The number of fish that comprise a 1,000-gallon truck load varies with the water temperature and the size and species of fish handled.

When fish are being collected or held in a holding tank the water is continuously aerated through air stones evenly distributed on the tank floor (Figure 18). Water temperatures for each holding tank are shown on dial thermometers at the control panel. Temperatures remain equal in active tanks, through which water is flowing, and in the channel. In inactive tanks standing with a load of fish, temperatures vary with air temperature and with the period of inaction. To date tank temperatures have been less than channel temperatures, probably because of cooling at night and the shade provided.

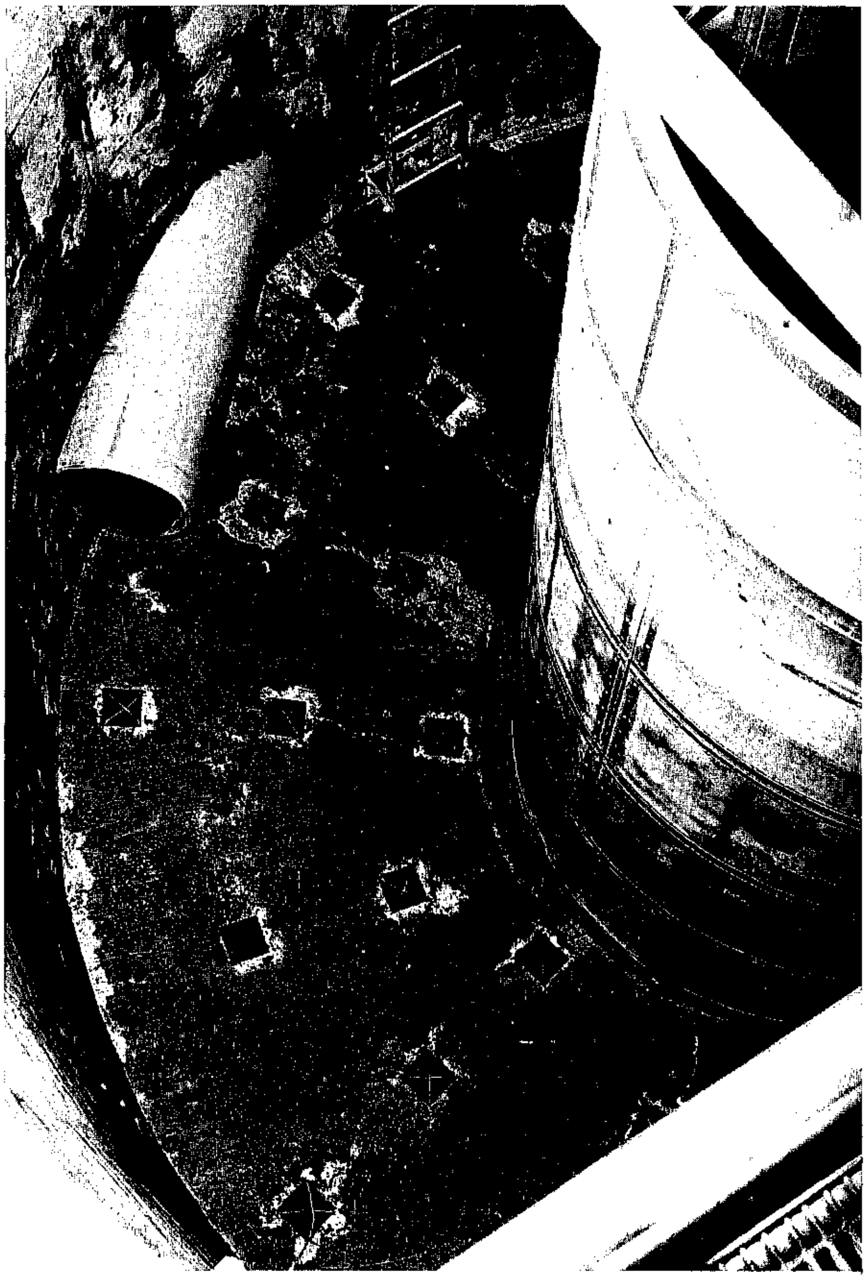
The four holding tanks should provide adequate capacity, even during seasons of much greater abundance of fish than in 1959 when 12 million fish were collected without drowding.

Operation of Fish-lift Bucket

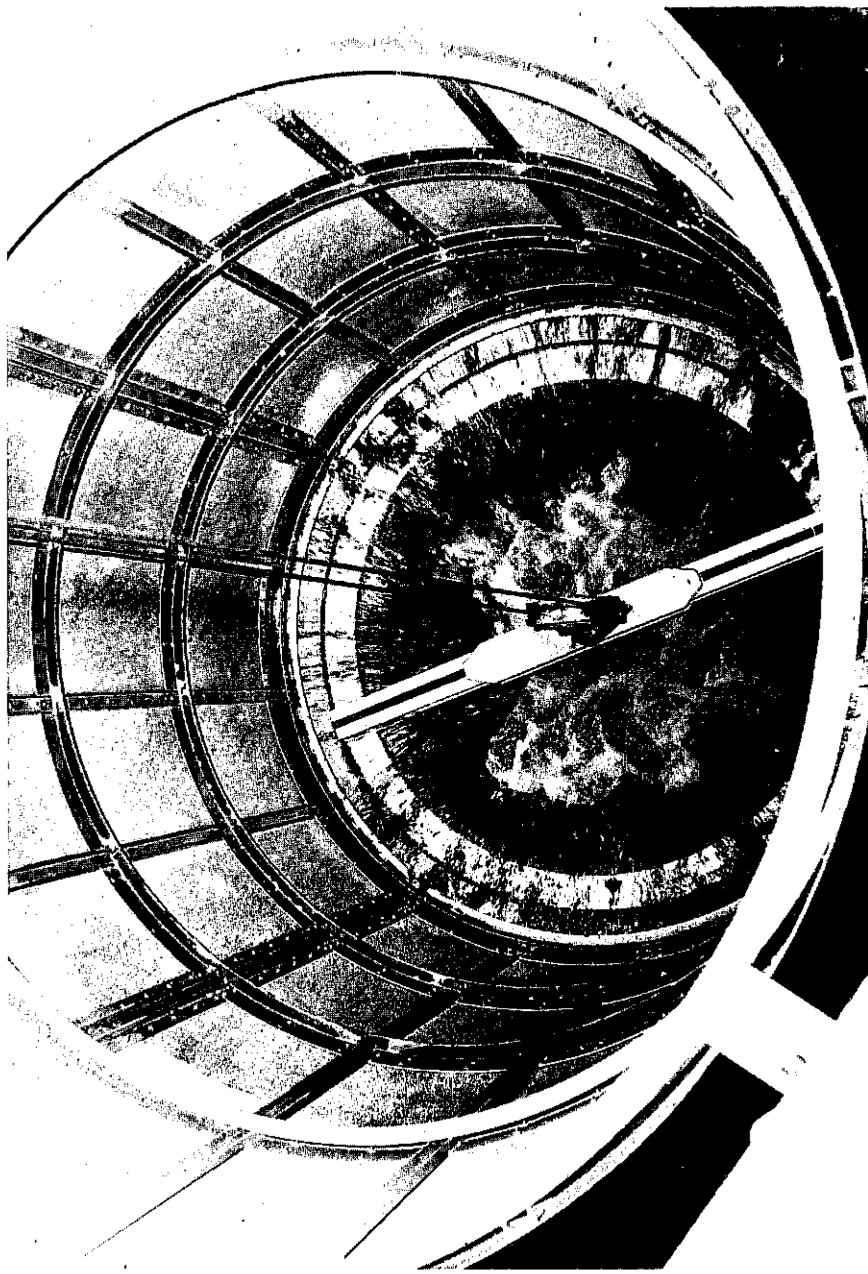
The fish lifting bucket is 4 feet 6 inches deep and 6 feet in diameter with a dished bottom. A lifting beam spans the top of the bucket at the center line. With a full load the bucket holds approximately 500 gallons.

Figure 19 shows the cylindrical screen in raised position and a load of fish being spilled into the bucket. When the bucket is filled it is raised with an electric hoist and carried on monorail to the tank truck (Figure 20). A hard rubber-ball check valve in the bottom of the bucket is raised to empty water and fish into the tank truck.

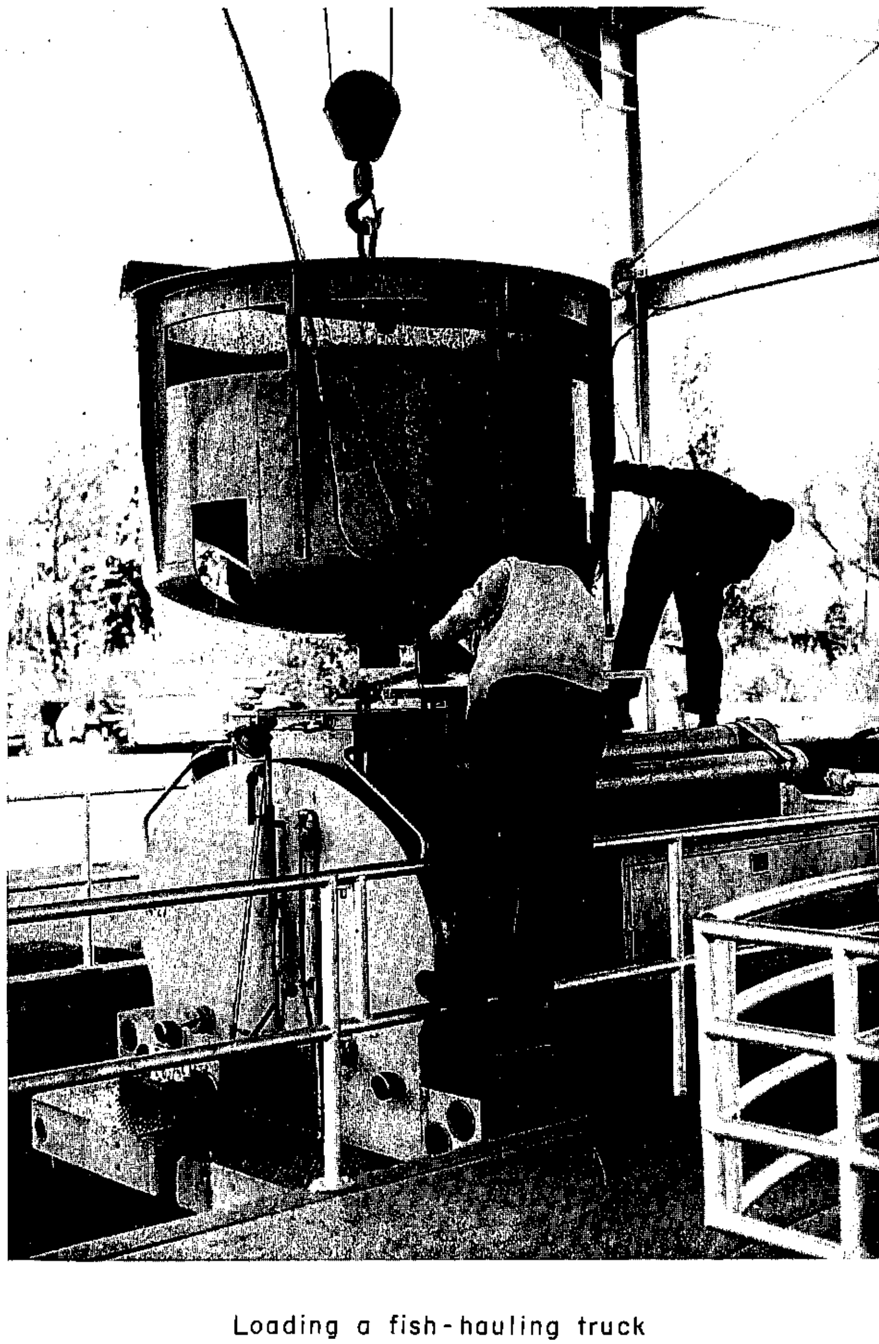
The four holding tanks



Interior of a holding tank. Note influent pipe, aeration stones on the bottom, and cylindrical water-outlet screen in center.



Lift bucket receiving a collection of fish



Loading a fish-hauling truck

It was necessary to increase the slope of the bottom bucket as originally designed as fish were stranded in the flat bottom.

Fish Counting Procedure

To determine when a truckload of fish has been collected in a holding tank periodic samples are taken. The samples are collected in selected 5-to 15-minute periods once every two hours in one of the holding tanks. A special fish-sampling bucket (Figure 21), operated the same way as the fish-lift bucket, is used to lift and transfer the fish for counting and identification as to species.

If the sampling periods were 10 minutes the estimated numbers of fish passing into a holding tank over a two-hour period would be 12 (number of 10-minute periods within two hours) times the numbers of fish taken in the sample. The numbers of fish accumulating within a tank is arrived at in this manner.

The problem originally encountered in this operation was in holding the fish for identification and for counting without injuring them prior to release back into a holding tank.

In the first counting scheme fish and water from the sampling bucket were emptied into a stationary tank. All water and fish were gradually released through a 6-inch diameter metal discharge nozzle at the bottom of the tank onto a flexible, wire-cloth conveyor belt traveling on a horizontal plane. The fish were to be identified and counted while being conveyed on the belt to a holding tank. This scheme was not satisfactory, however, because control of the release of water from the tank onto the conveyor belt was inadequate.

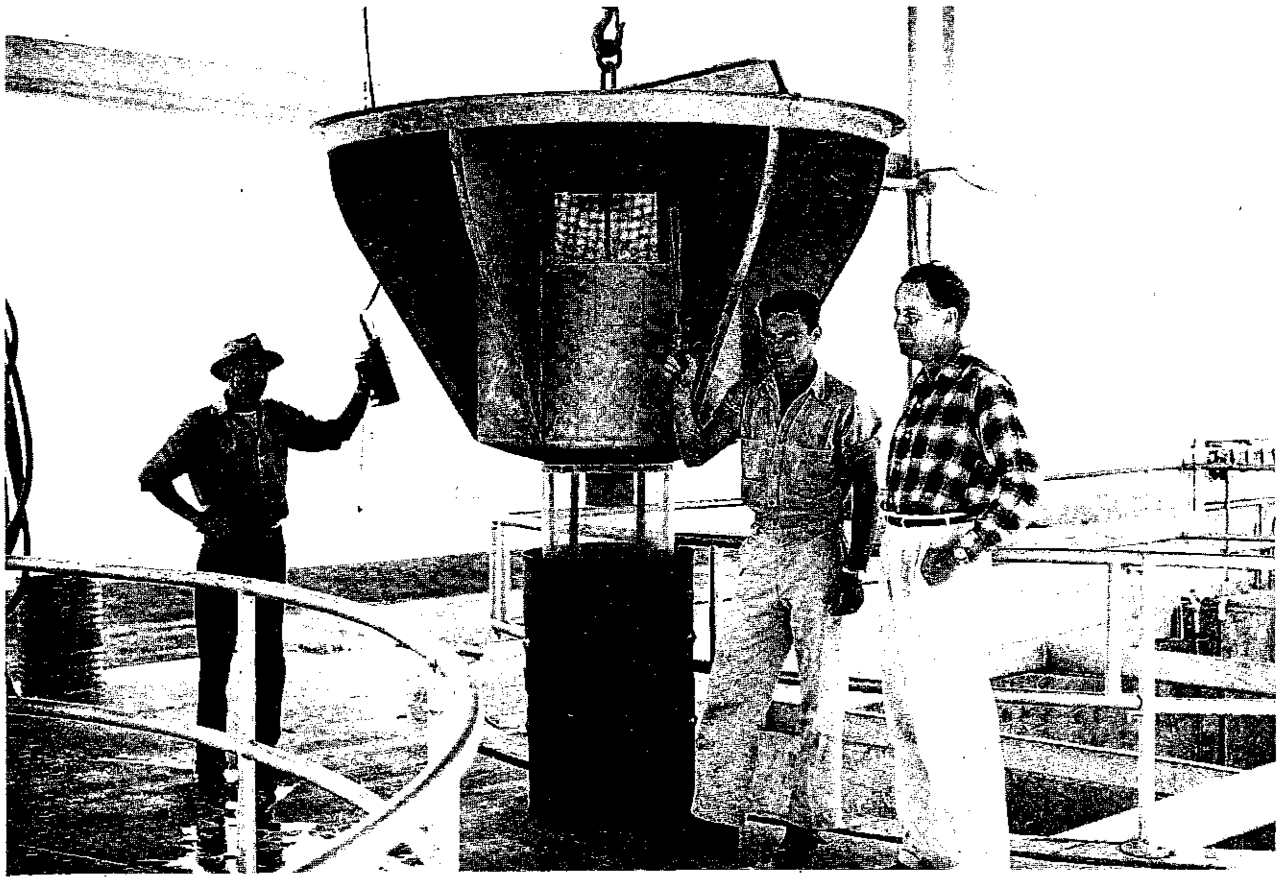
In the second plan the contents of the sampling bucket were discharged into a wire-cloth screen basket. The water passed through the screen into a large container while the fish were retained in the basket. The basket was then transferred into a metal-lined box containing about two inches of water. This shallow depth permitted easy counting and identification. However, because of the harsh physical treatment which the fish received as they were spilled onto the screen, a method was sought which would eliminate physical injury.

This was achieved by taking a 55-gallon steel drum and placing in it a floating assembly consisting of a cylindrical screen set in a metal pan to the underside of which is attached a float. The assembly is partially shown in Figure 21 with the upper rim of the screen flush against the bottom of the sample bucket. A valve is placed so a one-foot depth of water is retained in the drum. By lowering the sampling bucket onto the rim of the screen, the entire floating assembly is forced to the bottom of the drum. As the bucket is emptied into the drum the floating assembly rises retaining the fish in the pan. The screen is then removed and the fish dipped out of the pan, identified, counted, and returned to a holding tank.

Operation of Fish Hauling Trucks

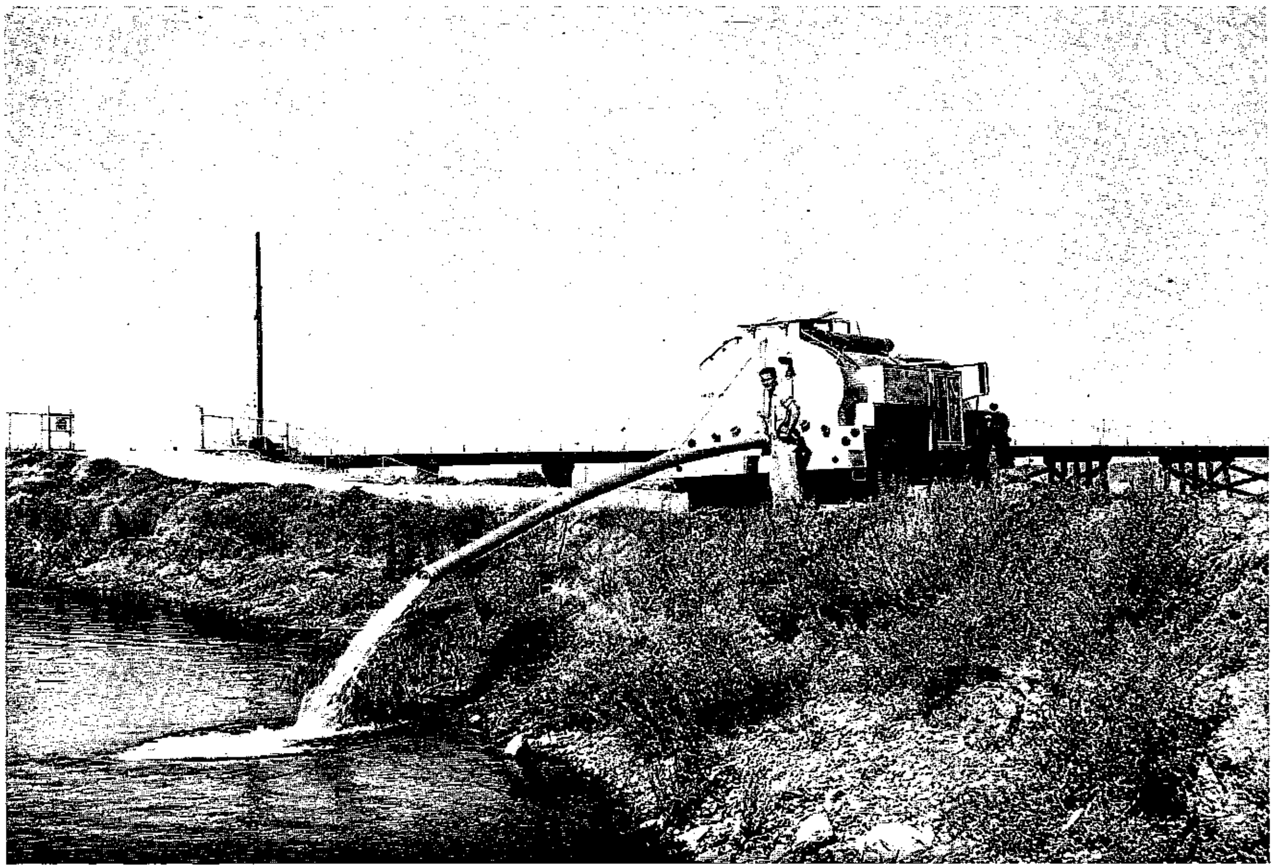
Two 1,000-gallon tank trucks are used for transporting fish (Figure 22). Each truck is equipped with a dial thermometer, circulating pump, refrigeration, and aeration. Two tubular air stones running the full length of the tank are positioned near the bottom, one at either side of the tank.

Studies were made to determine aeration, refrigeration, and water circulation requirements and to determine the relationship of these conditions to temperature and number of fish. The findings of these studies are shown in Figure 23.



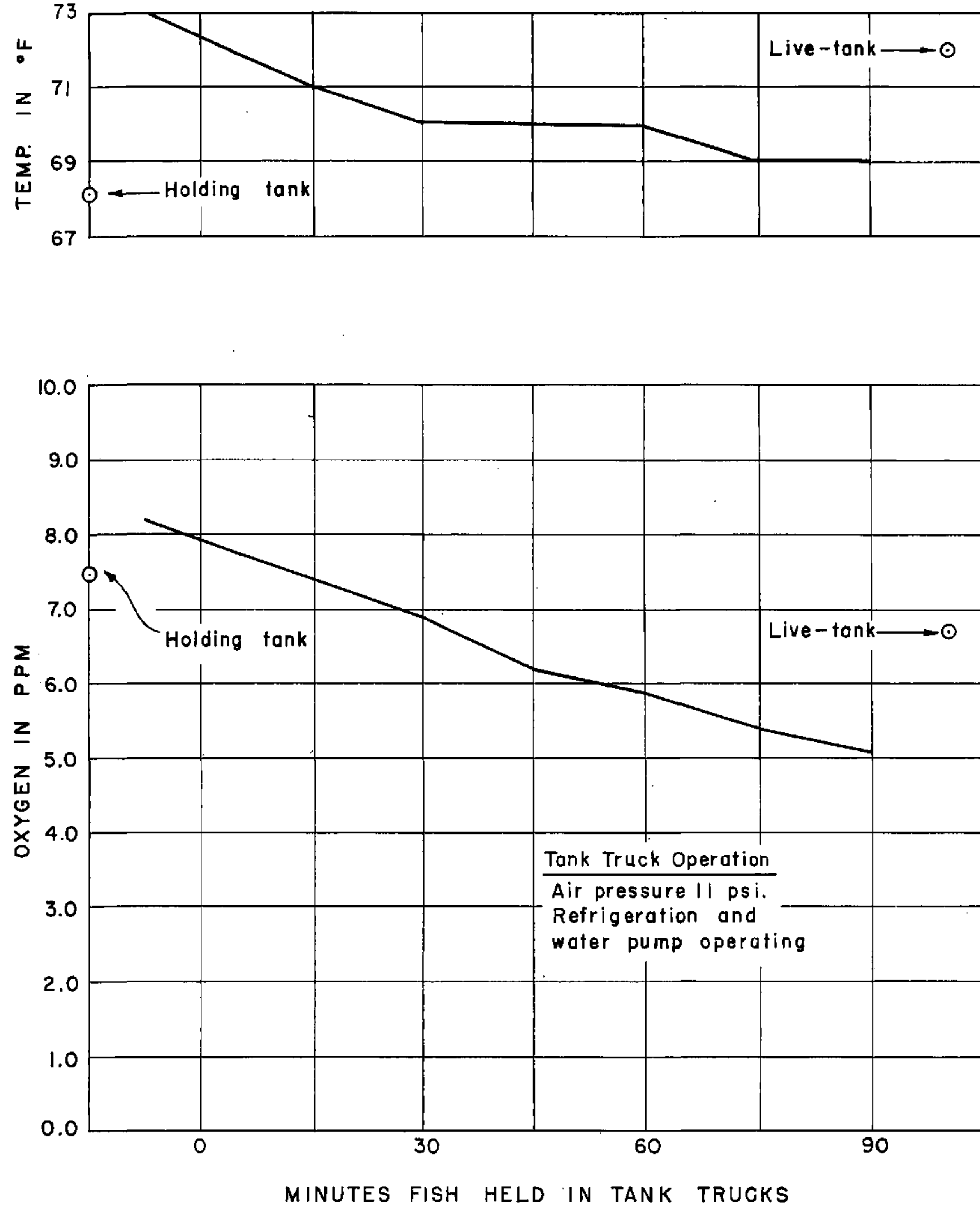
Sampling bucket and counting basket

Fig. 21



Truck discharging load of fish

Fig. 22



TEMPERATURES AND AMOUNTS OF DISSOLVED OXYGEN IN PARTS PER MILLION IN TRACY TANK TRUCK CONTAINING 41,160 TWO-INCH FISH

Table 9 shows physical conditions that were found satisfactory for trucking mixed loads of fish approximately two inches in length and held in the trucks less than two hours. With aeration supplied at the rate of at least 15 pounds per square inch no difficulty was encountered in providing an adequate supply of oxygen.

Tables 10A to 10F show the total numbers of fish of different size classes and species which can be safely in a load at given water temperatures. The approximate percentage of a truck load contained in a holding tank at any given time for the range of water temperatures anticipated can be quickly determined from these tables. To use these tables assume, for example, that the total numbers by species computed for a holding tank at 75° F. at a given time of day in July to be 16,000 striped bass and 12,000 white catfish, a total of 28,000 fish of size class "A", and 1,100 shad of size class "C". To find the percentage of a full truck load being held within a holding tank, first trace down the vertical column of Table 10A headed 30,000 (The closest figure to 28,000) to its intersection with the column on the 75° line. The figure at this point is 46 percent. Next, using Table 10C determine the percentage of a total truck load represented by the 1,100 class "C" fish in the holding tank. This figure is 16 percent. Therefore, the 28,000 class "A" fish and the 1,100 fish in class "C" represent 46 plus 16 percent of the tank truck load or 62 percent of the capacity. Additional fish may be collected to make up a full load if this can be accomplished within a reasonable time. Usually fish should be hauled at least once a day.

Table 9.--Truck Water Temperature, Oxygen Content, and Aeration*

Date (1958)	Time	Temp. °F	O_2 p.p.m.	Aeration (p.s.i.)	Numbers of Fish
July 16	1300	73	8.2	11	
	1315			11	
	1330	70	6.9	11	38,124
	1345	70	6.2	11	
	1400	70	5.9	11	
	1415	69	5.4	11	
	1430	69	5.1	11	
25	0829	74	6.8	15	16,754
	0903	73	5.0	15	
	0928	72	4.3	15	
	0937	70	7.7	15	
	1325	76	7.3	20	40,728
	1354	75	6.8	20	
	1425	75	7.0	20	
29	1122	76	7.0	20	15,146
	1146	76	6.9	20	
	1215	75	6.8	20	
	1246	74	6.8	20	
Aug. 1	1030	78	7.0		40,149
	1043	78	5.6	30	
	1105	77	5.3	30	
	1133	77	4.8	30	
	1205	76	5.2	30	

* Fish averaging approximately two inches in length were loaded into truck at times shown. Trucking time ranged from one to one and three-fourth hours.

Table 10A.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures*

Size Class A (Fish under 1.5 inches in length)

Water Temps.	Thousands of Fish																						
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
	(percent of load)																						
(°F.)																							
80	25	37	50	62	75	87	100																
79	22	33	44	55	66	77	88	100															
78	20	30	40	50	60	70	80	90	100														
77	18	27	36	45	54	63	72	81	90	100													
76	17	25	33	42	50	58	67	75	83	92	100												
75	15	23	31	38	46	54	62	69	77	85	92	100											
74	14	22	29	36	43	51	58	65	72	80	87	94	100										
73	14	21	27	34	41	48	55	62	68	75	82	89	96	100									
72	13	19	26	32	39	45	52	58	65	71	78	84	91	97	100								
71	12	19	25	31	37	43	49	56	62	68	74	80	86	93	99	100							
70	12	18	24	29	35	41	47	53	59	65	71	76	82	88	94	100							
69	11	17	22	28	34	39	45	51	56	62	67	73	79	84	90	96	100						
68	11	16	22	27	32	38	43	48	54	59	65	70	75	81	86	91	97	100					
67	10	15	21	26	31	36	41	46	52	57	62	67	72	77	82	88	93	98	100				
66	10	15	20	25	30	35	40	45	50	54	59	64	69	74	79	84	89	94	99				
65	10	14	19	24	29	33	38	43	48	52	57	62	67	71	76	81	86	90	95	100			
64	9	14	19	23	28	32	37	42	46	51	56	60	65	69	74	79	83	88	93	97	100		
63	9	14	18	23	27	32	36	41	45	50	54	59	63	68	72	77	81	86	90	95	100		
62	8	13	17	22	26	30	35	39	43	48	53	57	61	65	70	75	78	83	87	92	98		
61	8	12	17	21	26	29	34	38	42	47	51	55	59	64	68	73	77	81	85	89	94	100	
60	8	12	16	20	25	29	33	37	41	45	50	54	58	62	66	71	75	79	83	87	91	98	100

* Determined from known numbers.

Table 10B.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures

Size Class B (Fish between 1.5 and 2.5 inches in length)

Water Temps.	Thousands of Fish																
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
	(percent of load)																
(°F.)																	
80	29	43	57	71	86	100											
79	26	39	53	65	79	92	100										
78	24	36	49	60	73	85	97	100									
77	23	35	47	58	69	81	93	100									
76	21	33	43	54	65	76	86	97	100								
75	20	31	40	51	61	71	82	91	100								
74	19	29	38	48	58	67	77	86	96								
73	18	27	36	45	54	63	72	81	90	100							
72	17	25	34	43	51	60	68	77	86	94							
71	16	24	32	40	48	56	64	72	80	88	96						
70	15	23	30	38	46	53	61	69	76	84	92	100					
69	14	22	29	36	44	51	58	66	73	80	88	95					
68	14	21	28	35	42	49	56	63	70	77	84	91	98				
67	13	20	27	34	41	47	54	61	68	75	82	89	95				
66	13	19	26	32	39	46	52	59	65	72	78	85	92	98			
65	12	18	25	31	37	44	50	56	63	69	75	82	88	94	100		
64	12	18	24	30	37	43	49	55	61	67	74	80	86	92	98		
63	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96		
62	11	17	23	29	34	40	46	52	58	63	69	75	81	87	93	99	
61	11	17	22	28	34	39	45	51	56	62	68	73	79	85	90	97	
60	11	16	22	27	33	38	44	50	55	61	66	72	77	83	88	93	100

Table 10C.--Percentage of a Truck Load Determined From Known Numbers of Fish in a Holding Tank

Size Class C (Fish Between 2.5 and 4.5 Inches in Length)

Water Temps.	Thousands of Fish 1	2	3	4	5	6	7	8	9	10	11	12
	(percent of load)											
(°F.)												
80	25	50	75	100								
79	22	45	68	90								
78	20	41	62	83								
77	19	38	57	76	96							
76	17	35	53	71	89							
75	16	33	50	66	83	100						
74	15	31	46	62	78	93						
73	14	29	44	58	73	88						
72	13	27	41	55	69	83	97					
71	13	26	39	52	65	78	92					
70	12	25	37	50	62	75	87	100				
69	11	23	35	47	59	71	83	95				
68	11	22	34	45	56	68	79	90				
67	10	21	32	43	54	65	76	86	97			
66	10	20	31	42	52	62	72	83	93			
65	10	20	30	40	50	60	70	80	90	100		
64	9	19	28	38	48	57	67	76	86	96		
63	9	18	27	37	46	55	64	74	83	92		
62	8	17	26	35	44	53	62	71	80	89	98	
61	8	17	25	34	43	51	60	68	77	86	94	
60	8	16	25	33	41	50	58	66	75	83	91	100

Table 10D.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures

Size Class D (Fish over 4.5 inches in length)

Water Temps.	Thousands of Fish													
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
	(percent of load)													
(°F.)														
80	25	50	75	100										
79	21	43	65	86										
78	20	40	60	80	100									
77	17	35	53	71	89									
76	16	32	48	64	80	96								
75	15	30	45	60	75	90								
74	14	28	42	57	71	85	100							
73	13	26	39	52	65	78	92							
72	12	25	37	50	62	75	87	100						
71	11	23	34	46	58	69	81	93						
70	11	22	33	44	55	66	77	88	100					
69	10	20	31	41	52	62	72	83	93					
68	10	20	30	40	50	60	70	80	90	100				
67	9	18	28	37	47	56	66	75	84	94				
66	9	18	27	36	46	54	63	72	81	90	100			
65	8	17	26	34	43	51	60	68	77	86	94			
64	8	16	25	33	41	50	58	66	75	83	91	100		
63	7	15	23	31	39	47	55	63	71	79	87	95		
62	7	15	23	30	38	46	53	61	69	76	84	92	100	
61	7	14	22	29	36	44	52	58	66	73	80	88	95	
60	7	14	21	28	35	42	50	57	64	71	78	85	92	100

Table 10E.--Percentage of a Truck Load Determined From Known Numbers of Fish in a Holding Tank at Given Temperatures

Size Class E (King Salmon Between 1.5 and 3.0 Inches in Length)

Water Temps.	Thousands of Fish											
	5	10	15	20	25	30	35	40	45	50	55	60
	(percent of load)											
(°F.)												
70	13	27	41	55	69	83	97					
69	13	27	40	54	67	81	94					
68	12	25	38	51	64	76	89					
67	12	25	37	50	62	75	87	100				
66	11	23	35	47	59	71	83	95				
65	11	23	34	46	58	69	81	93				
64	11	22	34	45	56	68	79	90				
63	10	21	32	43	54	65	76	86	97			
62	10	21	31	42	53	63	74	85	95			
61	10	20	30	40	51	61	71	81	91			
60	10	20	30	40	50	60	70	80	90	100		
59	9	19	29	39	49	58	68	78	88	98		
58	9	19	28	38	48	57	67	76	86	96		
57	9	18	28	37	47	56	66	75	84	94		
56	9	18	27	37	46	55	64	74	83	92		
55	9	18	27	36	45	54	63	72	81	90	100	
54	8	17	26	35	44	53	62	71	80	89	98	
53	8	17	26	35	43	52	61	70	78	87	96	
52	8	17	25	34	43	51	60	68	77	86	94	
51	8	16	25	33	42	50	59	67	76	84	93	
50	8	16	25	33	41	50	58	66	75	83	91	100

Table 10F.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures

Size Class F (King Salmon over 3 inches in length)

Water Temps.	Thousands of Fish														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	(percent of load)														
(°F.)															
70	11	22	33	44	55	66	77	88	100						
69	10	21	32	43	53	64	75	86	96						
68	10	20	31	41	52	62	72	83	93						
67	10	20	30	40	50	60	70	80	90						
66	9	19	29	39	49	58	68	78	88	98					
65	9	19	28	38	47	57	66	76	85	95					
64	9	18	27	37	46	55	64	74	83	92					
63	9	18	27	36	45	54	63	72	81	90	99				
62	8	17	26	35	43	52	61	70	78	87	96				
61	8	17	25	34	42	51	59	68	76	85	94				
60	8	16	25	33	41	50	58	66	75	83	91	100			
59	8	16	24	32	40	48	56	65	73	81	89	97			
58	7	15	23	31	39	47	55	63	71	79	87	95			
57	7	15	23	31	38	46	54	62	69	77	85	93			
56	7	15	22	30	37	45	53	60	68	75	83	90	98		
55	7	14	22	29	37	44	51	59	66	74	81	88	96		
54	7	14	21	28	36	43	50	57	65	72	79	86	94		
53	7	14	21	28	35	42	49	56	63	70	78	85	92	99	
52	6	13	20	27	34	41	48	55	62	69	76	83	90	97	
51	6	13	20	27	34	40	47	54	61	68	74	81	88	95	
50	6	13	20	26	33	40	46	53	60	66	73	80	86	93	100

CHAPTER VI

MORTALITY IN THE TRACY FISH COLLECTING SYSTEM

Observations of Fish Mortality

Extensive fish mortality was observed at the Tracy Pilot Fish Screen Structure with fish collected by traveling screens (ibid., 1957, p. 31). The question of mortality in the prototype was raised in a Bureau of Reclamation hydraulic laboratory report which said: "It is reasonable to assume that utilization of the louver principle whereby the fish do not come in contact with traveling screens may result in lower mortality, but it is not known if any advantage in mortality is realistic as facilities did not exist to perform similar studies in connection with the louver installation during a comparable period when the striped bass were very small."6/ Additionally, dead fish had been observed floating when unloading a tank truck. Because of this observation and the uncertainty expressed in the laboratory report it was decided to check on the extent of mortality within the entire collecting system and also in truck transportation. In making this determination the trash rack, the primary louver structure, the secondary channel with its two lines of louvers, and the four concrete holding tanks were considered as constituting the collecting system.

Fish mortality due to turbulence in the secondary system, it will be recalled, is considered in Chapter III.

6/ Field and Laboratory Tests to Develop the Design of a Fish Screen Structure, Delta-Mendota Canal Headworks, Central Valley Project, California, Hydraulic Laboratory Report No. Hyd-401, Bureau of Reclamation, p. 10.

Mortality Test Procedure

The lateness of the 1958 pumping season, which did not begin until July 1, precluded any tests with king salmon. Suitable numbers of migrant striped bass were available, however, along with channel catfish, shad, and other species in the Sacramento-San Joaquin River System.

The number of mortality tests which could be conducted depended first upon when sufficient numbers of striped bass became available and later upon shortened collecting periods while the trash rack and louver structures were being cleaned.

For convenience, the live-tanks into which test fish were released were placed within the Tracy intake canal rather than at the usual release sites near the confluence of the Sacramento and San Joaquin Rivers where the much higher salinity and cooler water were considered beneficial for the recovery of exhausted fish. Therefore the mortality observed at the facilities may have actually been higher than normally occurs.

Fish were collected in a holding tank and held for a predetermined period. Upon completion of the holding period they were loaded into a tank truck and transported to the live-tank where dead fish were counted. Because they obviously could not be separated the count included those dead from natural or extrinsic causes as well as those which died somewhere in and because of the collecting system.

During the time that test fish were in a holding tank oxygen was provided by passing air through the diffuser stones. At the end of a holding period, the tank was drained and the test fish were flushed into a 320-gallon lift bucket and placed in a tank truck. The total number of fish used in each test was estimated from sample counts taken during the collecting period. Mortality was then calculated as the percent dead at the time of observation.

Collection, Holding, and Transportation of Test Fish

One of the four concrete holding tanks was used to collect fish for testing purposes. Once every hour or two hours during the collection period influent water was diverted into another holding tank where a 5- or 10-minute sample was collected for counting. To avoid influencing the mortality data these fish were not returned to the holding tank as it was considered that some might die through their having been handled.

To simulate operating conditions the test fish were hauled in the special hauling trucks for 1.5 hours. The trucks were also used to carry fish directly from a holding tank to a live-tank for counting. To load a tank truck it was partially filled with river water before dumping fish into it. The water in the truck was refrigerated, aerated, and recirculated during the 1.5-hour period that fish were being transported. However, only the aeration unit was in operation during the short time when fish were being transferred from a holding tank to a live-tank. Fish were released from the tank truck into a live-tank through a 12-inch diameter, 20-foot aluminum tube.

Measuring Mortality by Use of Live-Tanks

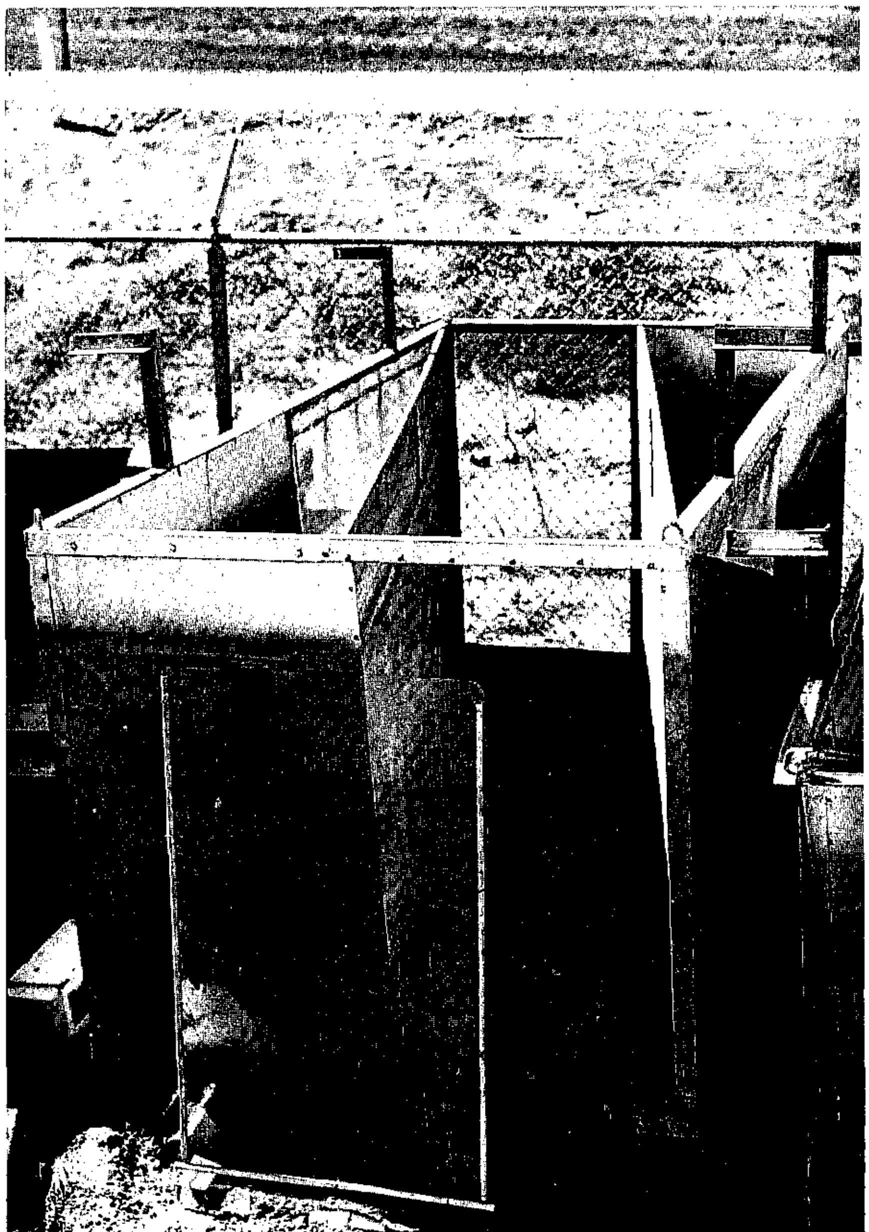
The two 1,500-gallon live-tanks to hold test fish for observation of mortality were located at the facility. Each tank was supported in a wooden raft which was provided with an overhead chain hoist to lift the tank out of the water. One of the tanks was placed above the primary louvers to facilitate immediate enumeration of the dead fish.

A special "modified live-tank" (Figure 24) was designed to facilitate separation of dead fish from a large number of live ones. In this tank a channel was constructed by placing two plywood walls diagonally across the inside. Both ends of the constructed channel thus constructed were covered with 0.1-inch mesh wire with the head screen easily removable.

In use test fish were released into this live-tank with the removable screen firmly in place. The tank was then positioned upstream to allow at least one foot per second flow to pass through the constructed channel. After 15 minutes the head screen was removed which allowed live fish to swim out. The dead fish were recovered from the stationary back screen while the tank was raised. In the afterbay live-tank, which was a conventional one, dead fish were recovered by dipping out both live and dead fish directly from the tank as it was raised.

The longest period that fish were held in a live-tank was 24 hours. The total observed mortality was low even though the live-tank was inadvertently overloaded (Table 11). The higher mortality for striped bass may have been due to the overcrowding within the live-tank in the primary afterbay. The tank truck was carrying less than its capacity, therefore, it seemed unlikely that the mortality increase was a result of confinement in a truck.

Extension of the holding period in a holding tank to four days apparently had no effect upon striped bass mortality; in fact, the observed mortality for 4 days happened to be lower than for 24 hours (Table 12).



Modified live-tank used in mortality studies - 1958

The series of tests recorded in Table 13 show the accumulation of dead fish at the end of the various holding periods. Dead fish were recovered in each of the 12 tests in the special live-tank. Fish which had been trucked for 1.5 hours were retained in this live-tank 6 hours for observation before the dead fish were recovered and counted.

Mortality apparently increased with the length of time that striped bass were held. The differences in size of striped bass and white catfish may account for the increased mortality in the 12-hour holding tank period. The observed mortality of shad is included for completeness of the recorded data. Irrespective of how young shad were when collected and held, no method was found for avoiding a significantly higher mortality in this species.

In summary, there appears to be a low rate of mortality among fish collected in the Tracy louver system.

Table 11.--Mortality of Fish Held One Day in a Live-Tank*

	Striped Bass (1 inch in length)	White Catfish (1 inch in length)	Other Species**	Totals
Total number	7,205	5,961	1,980	15,146
Number dead	400	60	60	520
Percent dead	5.6	1.0	3.0	3.4

* All fish collected for a period of 6 hours, held 8 hours in a holding tank, and 1.5 hours in a tank truck.

** Mostly 3-inch Sacramento blackfish (*Orthodon microlepidotus*).

Table 12.--Mortality of Fish Held Four Days in a Holding Tank*

	Striped Bass (under 1 inch in length)	White Catfish (under 1 inch in length)	Other Species**	Totals
Total number	4,139	25,013	8,972	38,124
Number dead	150	1,346	288	1,784
Percent dead	3.6	5.4	3.2	4.7

* All fish collected for a period of 15 hours and held 1.5 hours in a tank truck.

** Mostly 2-inch Sacramento blackfish and carp.

Table 13.--Mortality of Fish Held in a Holding Tank and in a Tank Truck*

Collected into holding tank only (Totals of 4 tests)

	Striped Bass (1.5 inches in length)	White Catfish (2 inches in length)	Other Species**	Totals
Total number	3,366	3,657	1,202	8,225
Number dead	36	13	49	98
Percent dead	1.1	0.4	4.1	1.2

Collected into holding tank and held for 12 hours (Totals of 4 tests)

	1 inch	1.5 inch		
Total number	8,085	7,023	1,260	16,368
Number dead	167	181	330	678
Percent dead	2.1	2.6	26.2	4.1

Collected into holding tank and held for 12 hours, then 1.5 hours in tank truck (Totals of 4 tests)

	1.5 inch	2.5 inch		
Total number	3,554	6,492	1,440	11,486
Number dead	45	55	94	194
Percent dead	1.3	0.8	6.5	1.7

* All fish collected during a 2-hour period.

** Mostly 3-inch shad.

CHAPTER VII

FINDINGS AND RECOMMENDATIONS

Findings

Based on tests in both the primary and secondary louvers, it seems safe to say that although collection efficiency at Tracy ranged from 65% to 100%, depending on the species and size of fish and the velocity of flow, it will exceed 90% most of the time, particularly now that debris removal has been improved and assuming turbulence in the secondary system will be decreased. The lower efficiency occurred with young catfish under one inch in length, and king salmon fingerlings during daytime periods when the approach velocity is 1.5 feet per second or less. Efficiences under these two conditions ranged from 65.0 to 85.8 and 87.8 to 89.2 percent, respectively. These latter efficiencies are considered tolerable for king salmon which move least in daylight hours. The loss of small catfish, though greater, should still be less than 25% most of the time.

The associated facilities, with the exception of the point of primary bypass discharge into the secondary, the sampling equipment for counting, and the trash rack, operated satisfactorily. A boom to deflect heavy trash from the trash rack was completed in the summer of 1960 (Figure 16a) to alleviate the trash problem and sampling equipment for counting fish was developed as described in Chapter V under "Fish Counting Procedures." A temporary installation (Figure 8) in the secondary system has reduced turbulence which caused holdup and loss of fish. Permanent modifications to alleviate the turbulence problem remain to be designed and constructed. Otherwise, the deflection of fish through the system and their collection, hauling and ultimate release was accomplished without undue disturbance or injury to the fish.

Recommendations

On the basis of the findings outlined in this report, it is recommended that:

1. The fish facilities be operated whenever significant numbers of fish need protection. This should be determined by the California Department of Fish and Game.

2. Operation of the primary and secondary facilities provide a bypass to approach velocity ratio of 1.2 to 1.0 feet per second with the exception that during the period when striped bass or channel catfish range in length from one-third to one and one-half inches, a bypass to approach velocity ratio of 1.4 to 1.0 be maintained whenever feasible. It is recognized that there will be periods when tidal height and pump capacity will require dropping to the 1.2 to 1.0 ratio.

3. The primary and secondary louvers and bypasses be examined frequently and kept clean at all times to minimize fish loss. Cleaning should be accomplished (a) during daytime and ebb tide so far as practical, and (b) immediately following trash removal from the trashrack. Also, a daily check should be made to determine whether or not the bypasses are clear of obstructions.

4. A check should be made periodically, perhaps by electric shocking, to determine the extent, if any, of predation existing within the entrances to the primary bypasses, this being the point where young fish would be most vulnerable.

5. Permanent modifications be made in the secondary for reducing the discharge turbulence of the primary bypasses.

6. Two lines of louvers be used in the secondary system.

7. Screened water be used at all times with a flow 1.6 times the active holding tank flow.

8. Holding tanks be operated as follows:

   a. Fill tank to be activated by backflow through the sump before inactivating the tank in use. This applies to both regular and sample count collections.

   b. Drain only the last 500 gallons of water and fish into the hauling bucket at rates and in a manner that leaves the least number of fish and greatest amount of sediment on the floor of the tank.

   c. When sediment on the tank floor is minimal, flush stranded fish from the holding tank into the hauling bucket by the momentary release of water from the influent pipe. When it is considered that the amount of sediment on the tank floor would be damaging to fish were it to be carried into the tank truck, the lifting bucket should be raised to remove the fish before flushing out sediment.

   d. Activate a tank immediately before inactivating the tank in use. This applied to both regular and sample count collections.

   e. Hold fish in numbers according to size and species considering water temperature (Tables 10A to 10F). Trucking should be accomplished at least once a day.

   f. Aerate water continuously during entire period of holding fish.

9. Make sample counts for estimating the total numbers of fish collected as follows:

   a. Make bi-hourly collections of ten minutes when the anticipated total numbers of fish to be counted is under 200.

   b. Make bi-hourly collections of five minutes when the anticipated total number of fish to be counted is over 200.

   c. In making counts employ sampling equipment described in Chapter V which provides that fish and water from the sampling bucket will fall into at least 12 inches of water.

   d. In counting enumerate the different species as specified by the California Department of Fish and Game.

10. Operate tank truck as follows:

   a. Previous to loading

      (1) Put 500 gallons of water in the tank.

      (2) Start aeration, circulation, and refrigeration equipment with aeration set at a maximum and refrigeration as required.

   b. Trucking and release

      (1) Be sure that water temperature in the truck is from 0 to 5 degrees F. lower than the tank water at loading.

      (2) Continue maximum aeration until unloading.

      (3) Use minimum time from loading the hauling bucket to unloading the truck at the release site.

      (4) Flush tank truck after initial tank discharge at the release site to remove all fish.

      (5) Employ in sequence at least six different release sites to insure that maximum time is available for dispersion of fish from each site.

APPENDIX A

Memorandum of Agreement Between the
Bureau of Reclamation and the U. S.
Fish and Wildlife Service

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MEMORANDUM OF AGREEMENT BETWEEN THE
BUREAU OF RECLAMATION AND THE U. S. FISH AND WILDLIFE SERVICE

Pertaining to Evaluation of the Efficiency and Effectiveness of the Tracy Fish Collection Facility, Central Valley Project, California.

WHEREAS, the Bureau of Reclamation, hereinafter referred to as the Bureau, has constructed the Tracy Fish Collection Facility to divert and collect fish from the intake channel to Tracy Pumping Plant; and

WHEREAS, the said Fish Collection Facility employs unique design principles which should be tested, appraised, and evaluated to establish operating criteria, and

WHEREAS, the U. S. Fish and Wildlife Service, hereinafter referred to as the Service, has participated in the Development of the design principles used and is best qualified by function to test, appraise and evaluate their biological aspects.

NOW, therefore, the Bureau and the Service, subject to approval by the Secretary, do hereby mutually agree as follows:

1. A joint program of testing, appraisal, and evaluation will be established as a necessary part of completion and proper operation of the Tracy Fish Collection Facility.

2. The Bureau will advance construction funds to the Service, pursuant to the program, said advance not to exceed $30,000. Funds unexpended for the purposes herein provided shall be returned to the Bureau.

3. The Service shall make available competent personnel to supervise and perform the biological phases of the program as jointly adopted, the total program to be appurtenant to the operation and maintenance of the Tracy Fish Collection Facility by the Bureau through the Chief, Tracy Operations Field Branch.

4. A joint monthly progress report shall be prepared by the Bureau and the Service covering both the mechanical and biological phases of the program and copies of said report shall be supplied to the California Department of Fish and Game. A final joint report covering the procedures, analyses, and findings of the entire testing, appraisal, and evaluation program shall also be prepared.

5. Office space, stenographic service, supplies, and equipment as needed will be furnished to Service personnel by the Bureau.

6. Expenditures made by the Service will be reported to the Bureau at the end of each calendar quarter.

This agreement shall be effective as of January 15, 1957, and shall continue until February 1, 1959.

BUREAU OF RECLAMATION

By /s/ A. N. Murray
Acting Regional Director

U. S. FISH AND WILDLIFE SERVICE

By /s/ Paul T. Quick
Acting Regional Director

APPROVED: 3/19/57

/s/ Hatfield Chilson

Acting Secretary of the Interior

APPENDIX B

Test Outline Form TO-80
and
Test Results Form TO-81

TO-80 (4-57)
Bureau of Reclamation

TRACY OPERATIONS FIELD BRANCH
TRACY FISH COLLECTING FACILITY

TEST OUTLINE

Date____________________ Outline Code________________ Test No.________

Date of Test____________________ Time From________________ To________________

Objective:

Equipment:

Method:

Personnel:

Submitted________________________

Approved________________________

TO-81 (4-57)
Bureau of Reclamation

TRACY OPERATIONS FIELD BRANCH
TRACY FISH COLLECTING FACILITY

TEST RESULTS

Date________________ Outline Code________ Test No._____

Variations from test outline:

Results:

Evaluation:

____
Fishery Biologist

APPENDIX C

OUTLINE OF OBJECTIVES AND METHODS FOR TESTING TRACY FISH FACILITY

Suggested by the Biometrics Unit
Bureau of Commercial Fisheries
U. S. Fish and Wildlife Service
Seattle, Washington

1958

OUTLINE OF OBJECTIVES AND METHODS FOR TESTING
TRACY FISH COLLECTING FACILITY
1958

OBJECTIVES: Tracy Testing Program

I. Evaluate the efficiency of the fish facility's components, including:

   A. The primary collection system (denoted by PCS)

   B. The secondary collection system

   C. Holding tanks, rotary screen, fish buckets, tank trucks, and other fish handling devices

II. Evaluate the effects of the facility with regard to:

   A. Predation

   B. Blocking or delay or migrants

   C. Other factors which might be included

III. Determine that method of releasing the fish into the river system which provides the best survival conditions, giving due regard to time of release, point of release, numbers released at a given time, dispersion of fish, etc.

IV. Establish standard operating procedures for the facility, based on:

   A. Results of studies carried out under I above

   B. Studies of handling techniques, methods of enumeration, recording methods, etc.

METHODS: Objective I-A

I. Efficiency of the Primary Collection System

A. Definition of efficiency:

The efficiency of the primary collection system (PCS) is defined as the proportion (E) of a group of N fish which is successfully diverted into the secondary collection system.

B. Mathematical expressions for efficiency:

Using the following notation, three expressions for E can be written:

Let N = Number of fish subjected to PCS during the time interval i, R = Number of fish successfully diverted during time interval i, and S = Number of fish not diverted during time interval i.

$$
\begin{aligned}
\text{Then } E_A &= 1 - \frac{S}{N} \\
E_B &= \frac{R}{N} \qquad\qquad (1) \\
E_C &= \frac{R}{R+S}
\end{aligned}
$$

N, R, and S must be estimated from some sampling program. For the present, let us denote sample catch data as follows:

C_1 = catch above PCS

C_2 = catch below PCS

C_3 = catch in bypasses

Let K_i ($i = 1, 2, 3$) represent a factor which will make C_1, C_2, or C_3 an estimate of the total numbers passing a particular sampling location during a given time interval. For example, the product $K_2\ C_2$ is an estimate of S. Then from equation (1) three estimates of E are available--any two of which are independent:

$$\hat{E}_A = 1 - \frac{K_2\ C_2}{K_1\ C_1}$$

$$\hat{E}_B = \frac{K_3\ C_3}{K_1\ C_1}$$

$$\hat{E}_C = \frac{K_3\ C_3}{K_2 C_2 + K_3 C_3}$$

These will be referred to as formulae A, B, and C.

C. Assumptions involved in estimating efficiency:

The utility of any of the three estimates will depend upon the quantities K_i and what assumptions can be made about them. Each of the factors K_1 and K_2 can be looked upon as the product of two components: (1) f, the fraction of expected catch actually taken--f being a measure of net efficiency, and (2) r, the expected sampling ratio assuming f to be equal to one. K_3 would be composed of just the second component, r, since the bypass nets strain the entire flow.

If the f components of K_1 and K_2 can be assumed to be equal, then the ratio K_2/K_1 can be evaluated from knowledge of the distribution of the fish--thus permitting the calculation of $\hat{E}_A$. In order to use $\hat{E}_B$ or $\hat{E}_C$ to estimate the efficiency of the PCS, it is necessary to (1) assume f to be equal to one or (2) evaluate f.

In using $\hat{E}_A$ or $\hat{E}_B$ as estimates of efficiency, it is assumed that during the sampling period all fish moving down (estimates by K_1C_1) either: (1) pass through the PCS, or (2) are diverted into the bypasses. In practice, there might be a third alternative: the fish do not make a choice during the sampling period. This would be a "holding up" of the fish, in which event, $\hat{E}_A$ would overestimate the efficiency and $\hat{E}_B$ would underestimate the efficiency. In this case, only $\hat{E}_C$ would give an unbiased estimate, provided that net efficiency is evaluated.

D. Use of Formulas A, B, and C.

At present it is planned to use $\hat{E}_A$ to estimate the efficiency of the PCS and to let $\hat{E}_B$ and/or $\hat{E}_C$ provide a check on that estimate.

E. Collection of information concerning assumptions involved in Formulas B and C.

Because the accuracy and utility of formulas B and C depend upon the efficiency of a sampling unit, it is proposed that certain information be collected concerning this item. Such information might be taken from (1) a laboratory study in which controlled numbers of fish are released in channels of varying area and are recovered by nets of the type used at Tracy, (2) a comparison of sample catch data behind a louver section of the PCS under two conditions: louver section in place and louver section raised, (3) analysis of discrepancies between formulas A, B, and C, and (4) marking and recovery experiments.

F. Background for experimental design.

The foregoing has been aimed at evaluating the efficiency of the PCS under a given set of conditions. If efficiency is dependent upon certain environmental factors (e. g., water velocity, etc.), it is not realistic to attempt estimates without specifying those factors in control at the time. This involves a consideration of the principles of experimental design which is taken up in section IV.

II. Sampling procedures for obtaining data needed to estimate efficiency: Formula A.

A. Definition of a sampling unit.

A sampling unit is one fyke net of the following specifications: 3' x 3' at the mouth, approximately 10 to 12 feet long, one mesh size to be used between March and mid-June and another mesh size to be used after mid-June.

B. Duration of a sampling period.

The duration of a sampling period will be 27 minutes unless observations indicate that some other period of time would be more efficient and practical.

C. Number of sampling units to be used per sampling period for obtaining estimates of efficiency.

Until sampling data indicate otherwise, nine nets will be used to sample a cross-sectional area above the PCS, and nine nets will be used to sample the area behind the PCS. Insofar as possible, all nets will be fished simultaneously.

D. Arrangement of the sampling units.

Until there is evidence indicating that some other sampling design is more efficient, the following scheme is proposed.

1. Above the PCS.

a. Four nets will be fished in fixed positions throughout all sampling periods. These four nets will furnish a "standard" set of data for comparisons between sampling periods. The positioning of these four nets will be based on the best available information as to where they might furnish the best estimate of the number of fish in the cross-sectional area above the PCS in any given sampling period.

b. Five additional nets will be fished in various patterns to determine the type of cross-sectional distribution to fish. This information will be used to determine the more efficient sampling design for obtaining data to be used to estimate the efficiency of the PCS.

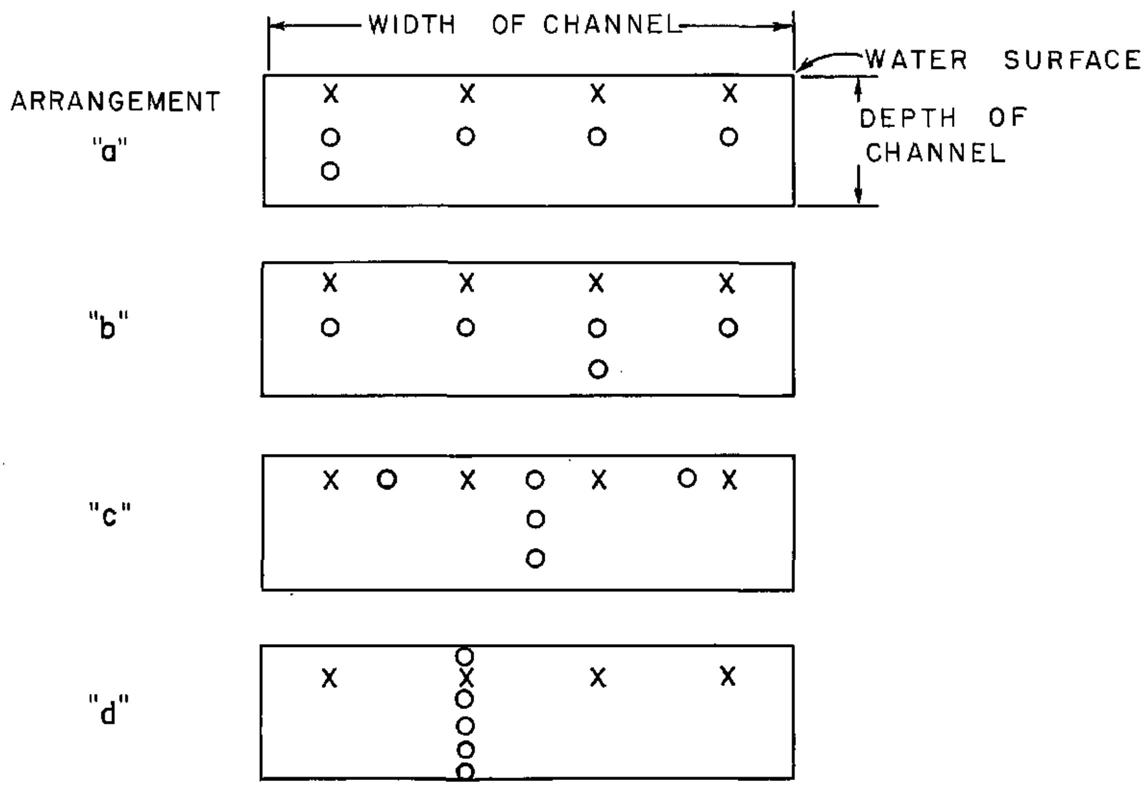
c. Some diagrams of various arrangements of nets above the PCS are shown in Figure 1. The spaces marked "X" denote fixed nets; the spaces marked "O" denote movable nets.

2. Below the PCS.

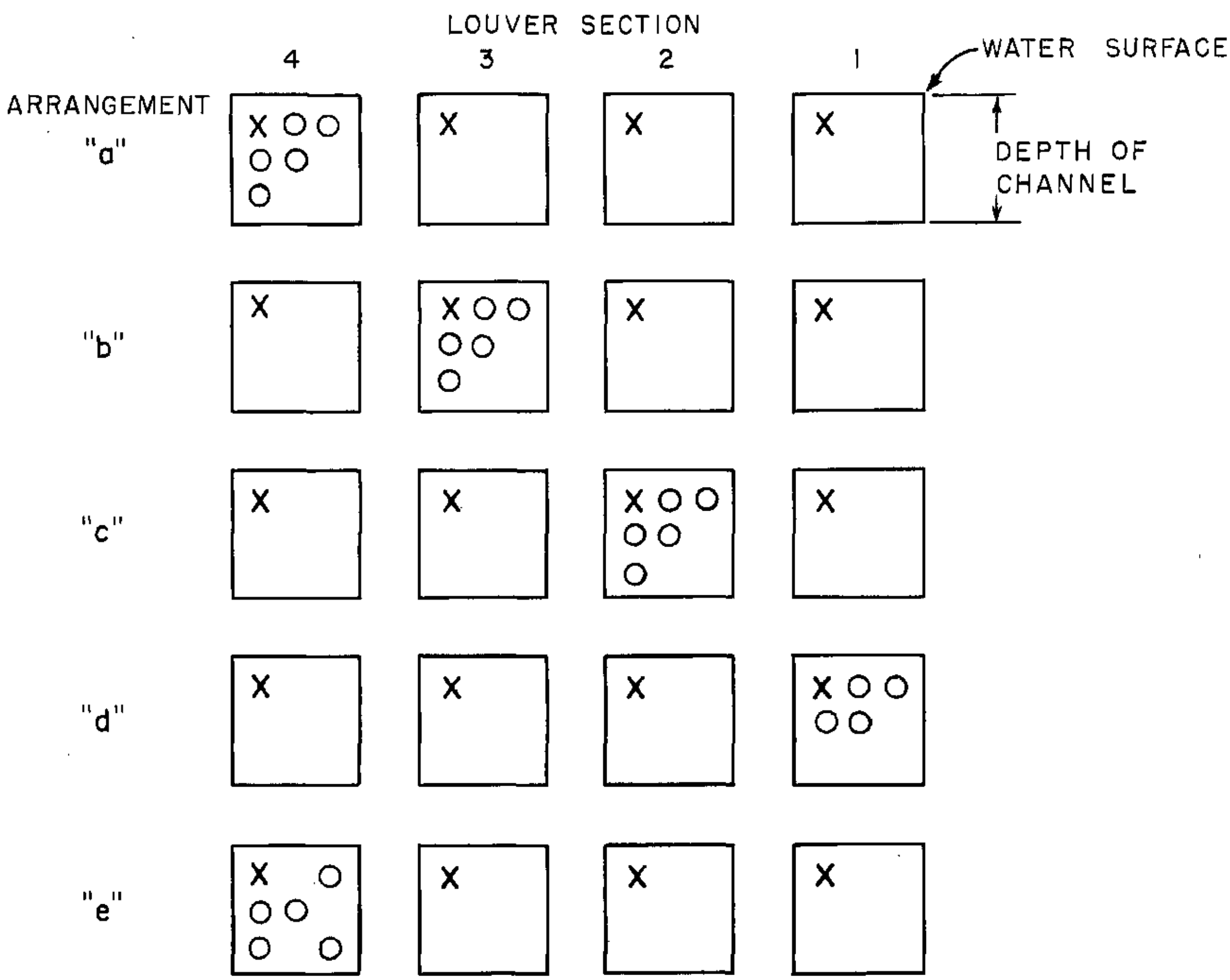
   a. Four nets will be fished in fixed positions throughout all sampling periods to obtain a "standard" set of data to be used for comparisons between sampling periods. There will be one fixed net behind each louver section of the PCS. The positioning of these four nets will be based on the best available information as to where they might provide the best estimate of the numbers of fish passing through the PCS in any given sampling period.

b. Five additional nets will be fished in various patterns to determine the distribution of fish behind each louver section in the PCS. Such information will be used to determine the most efficient sampling design for obtaining data to be used in estimating the efficiency of the PCS.

c. Some diagrams of various arrangements of nets behind the PCS are shown in Figure 2. The spaces marked "X" denote fixed nets; the spaces marked "O" denote movable nets.



EXAMPLES OF ARRANGEMENTS OF NETS ABOVE THE PRIMARY COLLECTION SYSTEM



EXAMPLES OF ARRANGEMENTS OF NETS BELOW THE PRIMARY COLLECTION SYSTEM

SPECIES	PERIOD	TIME	TIDAL STAGE AND CHANNEL VELOCITY (f.p.s.)							
			INCOMING				OUTGOING			
Salmon	April 1-May 5	Day	1.4	1.9	2.5	3.0	0.8	1.4	1.9	2.5
		Night	"	"	"	"	"	"	"	"
	May 6-June 10	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"
Large Striped Bass	April 1-30	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"
	May 1-30	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"
Small Striped Bass	June 1-20	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"
	June 21-Aug.15	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"
Large Striped Bass	Aug.15-Sept. 15	Day	"	"	"	"	"	"	"	"
		Night	"	"	"	"	"	"	"	"

CLASSIFICATION SCHEME FOR DETERMINING WHAT FACTORS AND THEIR LEVELS ARE UNDER STUDY

III. Sampling procedures for obtaining data needed to estimate efficiency: Formulas B and C.

Samples will be taken above and below the PCS as described for Formula A. In addition, samples will be taken within the bypasses of the PCS to estimate the number of fish guided into the bypasses during a sampling period. It is tentatively planned that one net (specifications to be spelled out later) will be fished in each bypass during the middle 15 minutes of each 27-minute sampling period.

IV. Experimental design: principles and application.

A. Background.

1. In section I-F it was pointed out that if efficiency changes with environmental conditions, it is unrealistic to attempt estimates without specifying these conditions.

2. Three requirements must be met for estimates to be realistic.

    a. Estimates of the reproducibility of the estimates of efficiency must be obtained at the same time as the estimates themselves.

    b. Evaluation must be done under a wide range of conditions.

    c. The experimental designs must be practicable.

3. Certain experimental "treatments", such as levels of abundance, etc., are largely beyond control. However, some test conditions or "treatments" are controllable (and also compatible with certain

pumping requirements), including flows and velocities and ratios of PCS bypass velocities to main channel velocities. It is with regard to these conditions that experimental designs will be considered.

B. General planning.

1. The Biometrics Unit will determine in advance of each "experiment" the relationship between flexibility in Tracy pump operation and environmental factors to be encountered.

    a. This will dictate requirements for short-term designs which will be set up.

    b. The processes of planning and conducting the work will be closely integrated.

2. Table 1 is helpful in examining in advance just what type of "treatments" are under study.

    a. Dates for each species and size divide the 1957 catches into two approximately equal portions.

    b. Knowing the number of Tracy Units operable in a given period, channel velocities possible for each tidal stage will be known.

    c. Knowing what the sampling operation involves, it should then be possible to estimate reasonably well the number of separate efficiency estimates obtainable in each sub-class (sub-classes are denoted by a dash). Other species, e.g., catfish, could be added to the table.

d. Individual comparisons of interest can be made. For example, does efficiency differ for chinook salmon at a channel velocity of 1.4 ft./sec. between incoming and outgoing tides for the same period?

3. Auxiliary information, including observations on the amount of trash, abundance of fish, turbidity, etc., will be used to determine whether differences such as might be observed in (d) above are confounded with factors which do not readily lend themselves to experimental control.

   Another type of auxiliary information involves sampling of catches above and below the PCS and in the bypasses to obtain length frequencies. Comparisons of lengths would provide information on the relative efficiency of the PCS for fish of different sizes within a given sampling period.

C. Specific designs.

1. No specific designs have yet been set up.

   a. The number of Tracy pumps operable under different conditions must be known.

   b. Further details of the mechanics of sampling must be known.

2. They will be set up during the 1958 season on a short-term basis.